THE

OSTEOLOGY OF THE COLYMBUS TORQUATUS;

WITH NOTES ON ITS MYOLOGY.

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THE *Natatores Brachypteri*, or *Urinatores*, so restricted as to exclude the Penguins, (*Ptilopteri*,) form an exceedingly natural group, quite closely adhering to a peculiar type of structure, as regards their bony framework and the muscles which act upon it. Their essential characteristics are found in the possession of a structure which, while it secures quite vigorous powers of flight, yet attains to by far its most perfect development in the production of natatorial powers, (unequalled except by those of the Penguins,) at a great sacrifice of capabilities for terrestrial locomotion. Progression on land is generally slow, awkward, and constrained; and is seldom or never protracted to any considerable distance, the bird always remaining in close proximity to the water. On the other hand, progression on or through the water is accomplished with a degree of facility and energy which at once stamps a peculiar character upon the whole tribe.

These remarks apply with particular force to that family of birds of which the common Loon may be considered as typical. In the genus *Colymbus*, the peculiarities of structure above alluded to reach their maximum of development, for the production of unsurpassed natatorial powers, at the expense of capabilities for terrestrial locomotion, which latter are remarkably imperfect. Both the osseous and the muscular system, therefore, of *Colymbus torquatus*, are probably typical of the morphology of these systems throughout the *Urinatores*, and are thus specially interesting and instructive as exemplifying the natatorial type of structure in a very perfect manner. The descriptive anatomy of them is applicable in a greater or less degree to the other genera of the tribe. The *Podicipidæ* are of course the most intimately allied; some of the genera of the *Alcidæ* may be more aberrant.

Although peculiarities are found in the whole structure of the bird, yet they of course are most marked in the posterior extremities; and I have therefore, in my descriptions, entered specially into detail regarding these parts, passing over other portions in a more summary manner. In the following pages, so far as the bones are concerned, it has been attempted to present the descriptive anatomy of the entire skeleton; while in the account of the muscles, only the more important have been noticed, special attention having been paid to those of the posterior extremities. In a paper like the present, it seemed

impossible to present a complete myology, while such a procedure would be of doubtful utility. The scope of the paper is perhaps expressed in its title. Whatever may be its deficiencies or inaccuracies, it is offered in the hope that it may contribute its mite to the sum total of our knowledge of the anatomy of the class.

Of the Skull.

In the adult skull, the various bones of the cranium are, with the exception of course of the pterygoid and the tympanic elements of the temporal, so completely anchylosed that even the traces of their original sutures are scarcely discernible. The same may be said of the majority of the facial bones, especially the nasal, intermaxillary, and superior maxillary. The fronto-maxillary "articulation," however, and the palato-pterygoid and tympano-malar, remain freely movable. I will first notice the individual bones of the head, as well those which are anchylosed as those which remain permanently separated, and afterwards examine the skull, as a whole, upon its several aspects.

The *occipital* forms the posterior, and a small part of the inferior, aspect of the skull. Its basilar process is nearly smooth and flat, somewhat of a diamond shape, bounded anteriorly by the occipito-sphenoidal anchylosis, more laterally by the petrous portion of the temporal, posteriorly by the atloid condyle and foramen magnum. Just anterior to the condyle there are two considerable depressions for ligamentous attachments; and just externally to these, two slight elevations. Laterally, the occipital spreads out and rises into two prominent processes, the apices of which are rough for the attachment of muscles. From these condyles and from the basilar process, the "spinous" element of the bone arches upwards toward the parietal, leaving inferiorly the large orifice, — the foramen magnum. On either side these "spinous" plates are much depressed and rough for the attachment of muscles, and are separated from the parietal bones by elevated curved crests. On the median line they rise up to form an arched longitudinal elevation. The foramen magnum is broadly oval in shape, its long axis being antero-posterior. Above, its margins are very thin, being formed by the thin "spinous" plates of the occipital; they become laterally considerably thicker. Inferiorly, the edge of the foramen is occupied by the single condyle forming the occipito-atloid articulation. Its face is exceedingly convex; its general outline a semilune, the cornua presenting upwards, the greatest convexity directly downwards. Around the foramen magnum are several other foramina, for the transmission of some of the cranial nerves.

Sphenoid. The basilar process of this bone projects directly forwards from the basilar process of the occipital, in the median line, having on either side the pterygoid and palate bones, from both of which it is entirely separated. In this species, in which the orbits are so defective as to their bony parietes, it forms nothing of the floor of the orbits, but, by a vertical lamella of bone which projects forward, it contributes to form the inferior portion of the very deficient septum which exists between the orbits. From the posterior part of the base of the bone, the two "orbital" processes or plates extend upwards, forwards, and outwards, as thin lamellæ. They form the posterior walls of the orbits, separating them from the cranial cavity. Each is pierced near the median line, at its lower border, by the very large subcircular optic foramen; and external to these, by a smaller opening for the ophthalmic division of the fifth nerve. The second and third divisions of the fifth together perforate the bone much further back and more externally, in the depression just above the body

of the tympanic bone. Just above the optic foramina are two others of considerable size, and of a regular quadrilateral shape. The alæ majores form that part of the skull intermediate between the zygomatic portion of the temporal and posterior orbital processes of the frontal.

Parietal. The complete anchylosis of the roof of the cranium leaves no traces of the original margins of these bones. The space which represents them is bounded posteriorly by the elevated crest marking the edge of the occipital, below and behind by the temporal, below more anteriorly by the alæ majores; on the roof of the skull they may be considered as projecting about as far forward as a line drawn between the two posterior orbital processes of the frontal. The space thus included is for a little distance on the anterior portion smooth, and covered only by the skin; but by far the greater portion of the bones form on either side rough, irregular, greatly depressed fossæ, generally styled the "temporal fossæ." These are entirely filled up, in the recent state, to the level of the rest of the skull by the temporal and masseter muscles. The two fossæ are separated from each other by a well-marked median longitudinal crest, from the anterior extremity of which two other equally elevated ridges proceed on either side to the posterior orbital processes, and form the anterior boundaries of the fossæ.

Temporal. This bone forms the infero-posterior angle of the skull, being situate between the parietal, occipital, and sphenoid. Superiorly, the "squamous" portion sends forward and downward the zygomatic process. The mastoid process seems to be indicated in that part of the bone which is continuous with the condyloid process of the occipital; it gives origin to the analogue of our *digastricus*. The petrous portion of the bone containing the osseous elements of the organ of hearing, lies internally on the inferior aspect of the skull, anchylosed with the side of the occipital basilar process. To the under surface of the zygomatic process is articulated the movable element of the temporal.

Os pedicellatum. This, the tympanic element of the temporal bone, articulates, by two separate, oval, very convex facets, placed side by side in a line oblique to the axis of the body, with two corresponding deeply concave depressions at the bottom of the fossa on the under surface of the zygomatic process. The depth of the depression in which the head of the pedicellate bone is received, together with a projecting border from the edge of the zygomatic process, tends to make the joint a very strong one.

From this articulating head the bone projects directly downwards and a little forwards for about three fourths of an inch. It first sends off its orbital process, — a stout compressed process of bone, projecting directly forwards and upwards into the orbit. This process has a considerable upward curve; its superior margin being concave, and running up quite to the head of the main bone; its inferior margin is convex, and merges into the main bone a little above the temporo-maxillary articulation. The top of this process is rough, for muscular attachments.

After giving off this orbital process, the bone becomes a little constricted into a "neck," upon which is supported the broad, irregularly shaped, and uneven head for articulation severally with the pterygoid, malar, and inferior maxillary.

The pterygoid facet is placed on the side of the head of the bone, just internal to, and below, the root of the orbital process. It is a single, obliquely elongated, smooth, very convex tubercle pointing inwards and forwards, on which the concave head of the pterygoid bone is placed. It presents something of the characters of the ball-and-socket joint, although rotation in all directions is not equally perfect.

Upon the opposite, *i. e.*, the outer aspect of the head of the pedicellatum, is placed the concavity for the reception of the head of the malar bone. It is on a lower level than the pterygoid facet, and presents more directly forwards. It is a nearly circular and exceedingly deep cavity. The small globular head of the malar is received into its concavity.

The somewhat extensive surface resulting from the expanded head of the bone is wholly occupied by the facet for the inferior maxillary. It is of an exceedingly irregular shape and uneven surface; in general terms, it may be said to be laterally much wider than long; to have a central depression bounded on each side and behind by elevations; and to be nearly divided into two lateral halves (corresponding to the lateral development of the head to produce the pterygoid and malar articulations), by a notch which cuts deeply into the posterior edge of the articulating surface To the inequalities of this surface, depressions and elevations in the lower jaw are accurately coaptated.

It is by this movable element of the temporal bone that the superior mandible receives the slight motion which it is capable of. The movements of this bone are transmitted by the malar to the superior maxillary, and by the pterygoid to the palatine, and thus the upper jaw is elevated or depressed according as the pedicellate moves forwards or backwards. The extent of motion that the upper jaw is capable of, however, does not seem to be as great as is the case with many other families.

Pterygoid. These are two straight slender bones about three fourths of an inch long, running obliquely inwards and forwards from the pterygoid facet on the inner edge of the head of the pedicellatum, to the posterior extremity of the palatine, with both of which they are movably articulated. Their shafts are slender, triangular on a transverse section, marked on their superior faces with a longitudinal groove. Both extremities expand into articulating facets. That of the posterior end is the largest; and besides the oval concave facet already noticed, by which it articulates with the pedicellatum, there is externally a small irregular projection which abuts against the inner side of the root of the orbital process of the tympanic bone. This seems to considerably restrict the extensive motion which ordinarily results from a ball-and-socket joint, and to give it rather the character of a free ginglymus.

The pterygo-palatine joint is a peculiar one. Two "claws," so to speak, project respectively from the upper and under surface of the bone, and grasp between them a small projecting point of the extremity of the palatine. The resulting articulation is most admirably adapted to its functions; chiefly that of *pushing* the palatine bones directly forward, but allowing also some inconsiderable lateral motion.

Frontal. This bone forms the whole of the roof of the orbits, but only a comparatively small part of the parietes of the cranial cavity proper. Its anterior border is quite straight, forming the directly transverse fronto-maxillary "articulation." The lateral margins are at first slightly bulging and convex, forming the anterior orbital processes; are then ascending and deeply concave, forming the superior margin of the orbits; and finally the bone stretches far downwards and backwards, to form the pointed prominent overhanging posterior orbital processes. Its posterior border is on the roof of the cranium anchylosed with the parietal, so as to leave no trace of the original suture; and in the back part of the orbits is equally fused with the orbital processes and alæ majores of the sphenoid.

Its superior surface is at first thick and rapidly ascending, forming the prominence of the forehead; in the rest of its extent it is flat, and gradually rises as it runs backward. It is marked in its whole length with a deep semilunar depression on each side, the con-

cavity of which is parallel with and corresponds to the concavity of the superior margin of the orbit; the convexities of the two meet on the median line, where they are separated by a longitudinal ridge. The bottoms of these semilunar grooves are pierced with numerous minute foramina. At the anterior extremity of each is a large oval foramen, which transmits to the mucous membrane of the nasal passages the duct of the "nasal" glands which lie in these depressions; the secretion of which moistens and lubricates the pituitary membrane. Posteriorly, on the superior surface of the frontal, there is formed by the divergence of these two nasal fossæ, and by the crests which form the anterior boundary of the parietal fossæ, a smooth, diamond-shaped, elevated tablet of bone, — almost the only part of the surface of the skull over which the skin is directly superimposed.

The chief noticeable feature on the under surface of the bone is the continuation forward of the osseous canal through which the olfactory nerves escape from the cranium, as deep well-marked canal, spreading out anteriorly into a still deeper and larger oval fossa. This fossa occupies part of the frontal bone, but still more of the ethmoid; external to the fossa is the foramen opening into the beds for the nasal glands, with a groove running from the anterior edge of the foramen into the nasal passages, just along the inside of the root of the lachrymal bone.

Ethmoid. This is little more than a thin vertical lamina, placed in the median line, its superior margin anchylosed with the inferior surface of the frontal; its inferior margin similarly united with the long, projecting, basilar process of the sphenoid; its sides forming anteriorly what there is of an imperfect inter-orbital septum. Its posterior edge is thin and sharp, and forms the anterior margin of the large circular opening between the orbits. Its anterior margin spreads out superiorly so as to become of considerable width where it is fused with the frontal; below it is deeply concave, running forward some distance, with a pointed extremity. The superior part of the lateral surface of the ethmoid is hollowed into a shallow fossa for the olfactory nerve, as already mentioned. There is nothing to correspond with our cribriform lamella, nor with the spongy convolutions of the lamellæ of bone which so preëminently characterize this bone in mammalia. It still, however, performs the ordinary functions of separating the orbits from each other, and the nasal from the ophthalmic cavities, and of supporting the ramifications of the olfactory nerves.

Bones of the Face.

The facial bones, like the majority of the cranial, are in adult life anchylosed more or less completely with each other; the complex osseous structure thus formed having, as a unit, slight motion with the cranial bones, by means of the fronto-maxillary, pterygo-palatine, and tympano-malar articulations. Owing, however, to their peculiar form, the precise line of anchylosis can in most cases be more readily detected than in the bones forming the cranium. All the bones of the human face are repeated, with, it is true, exceedingly diverse shapes, but yet so markedly as to give rise to no difficulty in homologizing them; but the *intermaxillary* bone, although fused with the supramaxillary as in man, in birds forms the most prominent and important element of all, — preponderating vastly over the superior maxillary proper.

Lachrymal. From its position and connections this bone would seem rather to appertain to the cranial than the facial group. It is a thick, stout process of bone, five eighths of

an inch long, projecting downwards and backwards from the under surface of the anterior corner of the frontal. It forms the continuation of the anterior boundary of the orbit. It projects downwards till it almost touches the malar bone, but is, however, quite unconnected with this or any other bone of the face, and does not have the least motion with them, being firmly anchylosed to the frontal. Besides forming the anterior continuation of the orbit, it forms a very partial and defective outer wall to the posterior part of the nasal passages. This bone, indeed, and the descending ramus of the nasal, are the only osseous lateral boundaries of the nasal passages throughout their whole extent.

Nasal. Firmly anchylosed basally with the root of the nasal process of the intermaxillary; movably articulated with the anterior border of the frontal. While its borders cannot be accurately defined, in consequence of its complete fusion with the intermaxillary, it sends downwards and forwards, at an acute angle, a conspicuous, stout, laterally compressed process which anchyloses with the superior maxillary, — appearing to be a direct continuation downwards of the intermaxillary. This process forms the posterior wall of the osseous boundary of the aperture of the external nares; forms with the lachrymal the lateral osseous boundary of the nasal passages; and connects the base of the nasal process of the intermaxillary with the superior maxillary bone.

Intermaxillary. This is by far the most important, as it is the largest and most conspicuous bone of the face; its various modifications in different families and orders of birds affording much the same data for zoölogical classification as do the teeth of the mammalia. In this species it measures three and a quarter inches in total length. Its outline along the culmen is slightly convex, especially terminally; both the mandibular and lateral outlines are a little concave. Distally, the bone consists of one piece, which is acutely pointed, arched superiorly, inferiorly with a deep longitudinal excavation, the beginning of the palate. About one and a half inches from the top it divides into three processes: a superior, mesial, "nasal" process, much the largest, running backwards as an elevated ridge supporting the culmen of the bill, anchylosed basally with the nasal bones and movably articulated with the frontal; and two lateral, basal, "mandibular" processes running along and forming the continuation of the tomia of the upper mandible, and finally merging by anchylosis into the superior maxillary, a little anterior to the zygomatic anchylosis.

The recess formed laterally by the divergence of the nasal and mandibular processes forms, with the nasal process of the nasal bone posteriorly, the large osseous boundary of the aperture of the external nares. It is an inch and a quarter in length, by a third of an inch high, sub-oval in shape, being narrow and compressed anteriorly.

The divergence of the mandibular processes leaves on the palate a narrow longitudinal opening, one fourth of an inch broad, covered with the lining membrane of the palate, except at the posterior part where begins the opening of the posterior nares. The fissure then becomes cleft in two by the vertically projecting vomer.

Superior maxillary. This bone is of inconsiderable size. It is difficult to define its contour with precision, as anteriorly it merges insensibly into the mandibular process of the intermaxillary; internally it is anchylosed with the palatine; superiorly the nasal bone becomes fused with it; while posteriorly it seems prolonged indefinitely into the long malar. That part of it which chiefly maintains its separate identity consists of a horizontal plate projecting directly inwards from the back and inner side of the bone towards the median line of the skull. This plate stretches to within a tenth of an inch of its fellow, the two being separated by the vomer, which passes between them. This represents the

palatal process. From its inner border all around there arises a thin, delicate, concavo-convex lamella of bone, projecting upwards, outwards, and backwards, its free rounded margin inflected downwards so as to partially occlude a quite deep fossa, — probably the analogue of our maxillary sinus, — antrum Highmorianum. While the bones forming this sinus are tolerably broad, so as to divide the long palatine fissure into an anterior and posterior part, they are so depressed vertically as scarcely to rise at all into the large nasal passages. But for the fact that it forms this quite conspicuous "antrum," the superior maxillary would seem to constitute little more than an osseous band of connection between the four bones already mentioned as anchylosing with it. The important part which it plays in mammalia generally in the formation of the upper mandible is here quite usurped by the intermaxillary.

Malar or "*zygomatic.*" Long and slender, measuring about two inches in length. They form the lateral boundary of the inferior aspect of the skull. Arising from a perfect anchylosis with the superior maxillary, they at first curve a little outwards; then more outwards, with an inclination downwards; finally curving rather abruptly inwards and slightly upwards to the outer edge of the head of the pedicellatum. They transmit the motion of the latter directly to the superior maxillary, as the pterygoid do to the palatine.

The malar bone, properly speaking, extends only three fourths of the distance to the pedicellatum, the remaining being made up by the true zygomatic element of the temporal. Traces of the fusion of the two are still clearly traceable in several oblique lines and sulci.

Palatine. The palate bones are long and slender, lying along each side of, and near to, the median line of the skull. The width of their separation from each other forms the palatal fissure. This amounts on an average to about a quarter of an inch; but at their posterior extremities the bones almost touch each other, being separated only by the width of the thin sphenoidal spine. They begin very near the anterior extremity of the superior maxillary bone, lying along its inner border, being more or less completely anchylosed with it, and extending to within half an inch of its posterior termination. Thus far they are simply plain, narrow, flattened spiculæ of bone; but shortly after leaving the maxillary bones, they dilate laterally into very thin lamellæ, their edges so much inflected downwards as to give a transversely concave outline to their inferior surfaces. This dilatation ends quite suddenly by a rounded free margin, which slopes inward and bends upward to form the little projections which are grasped by the ends of the pterygoid bones.

From the anterior portion of the superior aspect of these horizontal plates there rises quite gradually a thin vertical lamella, which curls upon itself upwards and inwards towards the median line, forming that part of the inner edge of the bones to which the vomer is articulated.

Vomer. The vomer, as usual, is situated directly in the median line, forming an incomplete septum between the right and left nasal passages. It is just one and a half inches in length. Its inferior border, for one inch anteriorly, presents an exceedingly thin edge. For the rest of its length it is bifurcate, — the right and left portions divaricating from each other at a very acute angle, to articulate with the corresponding palatines. They are probably, however, more or less completely anchylosed with the latter, so that little or no motion is allowed. The superior surface of the bone is deeply grooved longitudinally for nearly its whole extent; the edge of the vertical lamella, the conjoined sphenoid and ethmoid, being received into this groove, and riding freely through it during the movements

of the upper mandible. A little posterior to the termination of the ethmoidal spine, the bone sends out on each side a small but distinct lateral horizontal lamella. These run forward for half an inch, gradually narrowing till they no longer project; the groove along the superior surface of the bone also becomes obsolete; and the vomer continues a little way farther forwards, merely as a slender, very acute spine.

Inferior maxillary. Several of the original elements of which this bone is composed remain, as usual among the natatores, only incompletely anchylosed in adult life. The symphyseal elements present the most complete anchylosis, being firmly united for a little more than an inch. The angular and supra-angular pieces are also completely consolidated. The union between the two condyloid elements is less perfect, there being still traceable the evidences of their line of consolidation. The splenial element, however, remains quite distinct from all the others, except just at its lower end, where it is united to the angular. The piece produced by the union of the angular and supra-angular remains quite separate from the symphyseal element, being joined with it by the usual gomphosis. Along the inside of this joint the splenial element is applied obliquely; and posterior to it is the ordinary large unossified space. On the outside of the mandible proceeding from the gomphosal suture is the long oval foramen leading into the bone; and on the inside, nearly similarly situated but lower down, is a shorter and broader one.

In its general outline, this bone is quite straight, the rami not rising above the plane of the body of the bone, and the articular surface being on a level with its superior border. The tomal edge of the bone is almost perfectly straight, as far from the tip as the symphyseal element extends; then the superior border rises above the level of the articular facet, with an irregularly indented and somewhat curved outline; the principal elevation forming the "coronoid" process. This curved elevation terminates posteriorly in the depressed, broad, irregularly indented articular surface, — the inequalities of which are accurately coaptated to those of the articular facet on the os pedicellatum.

Posterior to the articulation, almost immediately continuous with it, is the well-defined triangular depression, presenting backwards and upwards, for the attachment of the principal depressor of the lower jaw, the so-called "digastricus." This space is bounded by well-defined raised borders; its inferior angle forms the posterior extremity of the bone.

The inferior edge of the bone is sinuate for its whole length. It is nearly straight from the tip as far as the consolidation of the symphyseal elements extends. Then, with a slight convexity, it curves upwards, and again downwards to the angle, forming an extensive concavity from the termination of the symphysis to the angle. The angle is pretty well marked though not acute, and it does not project much further below the level of the bone than the coronoid process does above it. From the angle, the inferior outline runs backwards with a moderate degree of upward obliquity, to just opposite the posterior border of the articulating surface, where it turns downwards with an abrupt concavity, to terminate at the apex of the triangular space above mentioned.

In its general shape and structure, this bone is very strong. The symphyseal elements are quite thick as well as deep, and their union very firm. More posteriorly, the bone is thinner, but this is compensated for by its greater depth. The articulating surfaces are very strong; and the total want of an obliquity in the line of union of the rami with the body of the bone confers a shape upon it which insures great stability and firmness.

Of the Cranium as a whole. Having considered the several individual pieces which go to make up the cranium, we will briefly notice the general characteristics of the skull as a

quadrilateral pyramid, of which the tip of the bill is the apex, the occipital bone chiefly the base, and the superior, inferior, and two lateral aspects respectively the four sides.

The *base* presents rather a pentagonal outline. Superiorly, the two occipital crests converge at an angle on the median line, terminating below on each side with the mastoid processes. The lateral boundaries of the pentagon are formed by the pedicellate bones, the tempero-maxillary articulation, and the surface at the end of the inferior maxillary bone for the attachment of the digastricus. The fifth side of the pentagon is an imaginary line drawn from the posterior extremities of the rami of the lower jaw. Exactly in the centre of this pentagon is the semilunar condyle for the cranio-vertebral articulation; just above it is the large oval foramen magnum, between which and the occipital crests lies the flat, depressed "spinous" plate of the occipital, — the two sides of which rise into a longitudinal ridge at their union along the median line. On either side, the mastoid processes project conspicuously. Beneath these, and between them and the ossa pedicellata, are situate the internal organs of hearing. The space around the foramen magnum is pierced by several foramina for the transmission of nerves.

The *superior aspect* of the skull is bounded posteriorly by the occipital ridge, laterally by the parietal bones, the superior margins of the orbits, and the sides of the intermaxillary. The zygomatic processes of the temporals are the first lateral protuberances from behind forward; between these and the post-orbital processes, the crotaphyte depression is deep and well marked. The post-orbital processes are long and acute, the width between their apices representing the greatest lateral width of the skull. Anterior to these, the margins of the superior aspect of the skull are deeply concave, by the indentation formed by the upper margins of the orbits; the ante-orbital processes form a slight concavity on each side, just posterior to the fronto-maxillary suture. The tapering intermaxillary bone forms the remainder of the boundary of this aspect of the skull; its superior surface is occupied, as far forward as the post-orbital processes, by the large, deep "temporal" fossa, formed chiefly, however, by the parietal bones. Along the margins of the orbits lie the two long semilunar depressions for the nasal glands, separated by a median ridge from each other, their divarication posteriorly leaving between them and the temporal fossæ a central elevated, smooth, lozenge-shaped space. At their termination the glandular depressions are perforated with oblique oval foramina, which transmit their ducts through to the nasal cavities. The curved fronto-maxillary suture extends transversely across from side to side, its convexity presenting backward; the smooth nasal bones come next; and, taking its origin from between them, and stretching from the frontal bone to the tip of the bill, is the intermaxillary.

The *inferior aspect* is bounded laterally and apically by, and contained chiefly within, the two sides of the lower jaw, which divaricate from the symphysis, and extend the whole length of this aspect of the skull. Posteriorly, on the median line, lies the basilar portion of the occipital; just anterior to it, the spheno-occipital anchylosis, from which runs forward in the median line the elongated vertical spine of the sphenoid, to be received into the cleft of the vomer, and there anchylosed with the ethmoid. On either side of this spine are the pterygoid bones, running backward from the pterygo-palatal articulation, and diverging outwards to join the head of the pedicellate bones. More anteriorly, the flat, elongated palate bones extend the whole distance from the pterygoid to the bases of the superior maxillary, lying on either side of the median line, the vomer being interposed between them, and articulated with them by its posterior bifurcated extremity. As far as the anterior extremity of the vomer, the spaces leading up into the orbits and nasal passages

have been divided along the median line into a right and left; but beyond this the palatal fissure is not cleft, but a single broad opening leads into the nares. The anterior single, and posterior double fissures are, however, continuous with each other, as the superior maxillary does not extend far enough inwards to meet the vomer.

The *lateral aspects* are each of a subtriangular shape, bounded by the margins of the three surfaces just described, with the planes of which they are united nearly at right angles. Their union with the posterior aspect is, however, at less than a right angle, in consequence of the lateral tapering of the skull from base to tip. Posteriorly the mastoid and zygomatic processes form conspicuous projections, below and internal to which are the internal organs of hearing. Anterior to this, extending between the under surface of the zygoma and the inferior maxillary articulation, is the pedicellatum, sending upward and forward into the orbit its orbital process. Just above the root of this process is the large circular foramen leading into the cranium, which transmits the second and third divisions of the fifth nerve; and the pterygoid bones are seen starting from just internal to the root of the orbital process, and running inward to the palatal.

The orbits occupy by far the largest portion of this lateral aspect of the skull. As usual among the *Natatores* they are exceedingly defective, not only as to bony margins, but as to septa between the two, and between them and the nasal and pharyngeal passages. The roof is formed centrally by the slight expansion of the frontal bone; the strongly developed post-orbital processes make a more complete arch posteriorly; while anteriorly, the slightly developed ante-orbital processes are eked out by the large strong lachrymal bones, which project downwards and backwards from the frontal quite to the malar, and complete the margin anteriorly. A very imperfect floor for the orbits is afforded by the slender elongated malar, the superior border of the inferior maxillary just within the malar, and by the horizontal expansions of the palatal. But the orbit is most defective posteriorly, where a bony parietis is quite wanting, and its place supplied by the temporal, masseter, and pterygoid muscles. The septum between the two orbits is formed by the vertical lamina of the sphenoid and ethmoid, but is very defective, a large circular aperture, more than half an inch in diameter, being closed only by dense membrane. Just at the posterior edge of this septum are seen the very large foramina for the optic nerves. There is really only one foramen leading into the cranium; but this is divided into two by the posterior edge of the vertical sphenoidal lamina, so that the nerves enter the two orbits by separate orifices. Other foramina, for the transmission of nerves and vessels, are found immediately about the optic. On the roof of the orbit is seen the longitudinal groove, emerging from the bony canal which transmits the olfactory nerve; and anterior and external to it, the large oval aperture which gives passage to the duct of the nasal gland. There is no bony septum between the orbits and the nasal passages.

Just anterior to the orbits, and separated from them by the lachrymal bone, is a triangular space. It opens into the orbits and the nasal passage, and communicates directly with its fellow, and projecting up in it is seen the horizontal incurved lamella of the superior maxillary. It is bounded below by the fused malar and superior maxillary bones, posteriorly by the lachrymal, anteriorly by the descending process of the nasal. This separates it from a large suboval aperture between the mesial and lateral rami of the intermaxillary, which forms the osseous margin of the external nostrils. It is one and a fourth inches long, by one fourth broad. Its axis is parallel with the nasal process of the intermaxillary, and therefore somewhat oblique to the longitudinal axis of the whole skull.

This aperture communicates directly with its fellow, and also with the palatal fissure, as as well as with the nasal passages generally.

Of the Vertebral Column.

Cervical vertebræ. The cervical portion of the spinal column consists of thirteen vertebræ. These, as usual among *Aves*, are very freely movable upon each other, not only antero-posteriorly in the direction of the axis of the body, but the lateral movement is also exceedingly free. There does not appear, however, to be anything very peculiar in their articulations with each other. The vertically concave and horizontally convex facet upon the posterior extremity of one vertebra is received into the vertically convex and horizontally concave anterior extremity of the next succeeding; and the smooth flat facets upon the oblique processes glide in the ordinary way upon each other. The planes of these articulations are so arranged as to produce, taken together, the ordinary "sigmoid" flexure of the neck of the bird. The feature of the extensive lateral motion of the neck appears to be more strongly marked than is ordinarily the case among the *Urinatores*, except perhaps the *Podicipidæ;* the long-necked genera of which, such as *Æchmophorus*, etc., probably surpass it in this respect. This lateral motion is most extensive between the lower cervical vertebræ.

Although these vertebræ possess characters which most readily separate them from those of any other portion of the column, they yet differ greatly from each other, in different portions of the neck. Throwing out of consideration the atlas and axis, which of course are quite unlike the others, we still find that scarcely any two vertebræ possess exactly the same shape, size, and special characters. Beginning with the third vertebra, and proceeding backwards, we find that the length of the bodies increases successively to about the eighth or ninth, when it again decreases rapidly, so that the last one is not so long as the third. The body of the third is thin, being exceedingly compressed vertically; and coincidently with the lengthening of each one successively to the eighth or ninth, they grow wider, and comparatively not so deep vertically; those that follow, however, do not again grow more compressed as they shorten; but on the contrary become broader and broader, so that the last one is as wide as deep, and very stout and strong. With this widening, there is also, towards the posterior extremity of this portion of the spine, a very high development of the transverse processes of the anterior extremities of each vertebra. This is so considerable, that the width across these transverse processes much exceeds the length of the whole vertebra. These processes are also exceedingly stout, with several roughened eminences for muscular attachments; and the foramen for the vertebral artery, which their two roots form, is as large as the spinal canal itself. Now as we proceed up the neck to the head, these transverse processes project less and less from the bodies of the vertebræ, and become less robust and angular, at the same time that they are antero-posteriorly elongated; and possess regular lamelloid walls, so as to form rather canals than simple foramina for the artery.

The "styliform processes" or "rudimentary ribs" appear to arise from the posterior aspects of the summits of each of the transverse processes, beginning with the third vertebra. They are directed backwards, exactly parallel with the axis of the column, and, according to their length, form a more or less complete osseous covering and protection to the vertebral artery during its passage between any two contiguous foramina. These

styliform processes on the third vertebra reach quite to the transverse processes of the next succeeding, and, by keeping pace with the lengthening of the vertebræ themselves, are longest absolutely on the eighth and ninth vertebræ. They now, however, rapidly shorten, and lose their very peculiar features, until on the last cervical vertebra they are merely little pointed projections from the posterior aspect of the transverse processes. This fact of their rapid absorption towards the thorax renders the determination of the first true dorsal rib perfectly easy. These styliform processes are firmly anchylosed with the transverse processes and bodies of the vertebra to which they appertain, but have no connection, other than ligamentous, with the next succeeding one.

The superior spinous processes are well developed on the anterior vertebræ, as prominent crests or keels, running the whole length of the surfaces of the bodies; so much laterally compressed as to be thin laminæ of bone rather than "spinous processes." Their shape on the third and fourth vertebræ is not unlike that of the keel of the sternum. They gradually decrease in size as they proceed backwards; until, on the ninth and tenth vertebræ, they amount to little more than slight compressed tubercles. These enlarge again on the eleventh and twelfth, and on the thirteenth have assumed the general features of those on the dorsal vertebræ. Between the dorsal surfaces of any two contiguous vertebræ there is the ordinary aperture, closed only ligamentously, leading into the spinal canal.

The inferior spinous processes have the same general characters as the superior, — *i. e.*, they are found well developed at both extremities of the neck, but disappear in the central portion. Thus the third vertebra has a very large, well-developed process, whose base occupies the whole length of the body of the vertebra. This is much smaller on the fourth, is scarcely appreciable on the fifth, and is totally wanting on the successive ones to the eleventh. On this one, however, a spinous process reappears abruptly, being larger than any of the anterior ones, and is especially noticeable for its great projection forwards and downwards, and its exceeding thinness. The twelfth and thirteenth processes are successively smaller than this, but partake of all its general characters of shape.

The *axis* is chiefly noticeable for the great development of its ventral and dorsal spines, the former of which extends far downwards as a thin compressed lamella of bone, larger than the ventral spine of any vertebra except the eleventh. Nearly all of the body of the vertebra seems to be really comprised in this spine; and the facet for the articulation of the body of the third vertebra is situate on its posterior edge just at its base. The roof of the spinal canal is quite flat, and from its median line rises the dorsal spinous process, not really so large as the ventral, but still quite stout and prominent, and terminating in a thickened tuberculous apex. The flat roof of the spinal canal spreads out posteriorly into the transverse processes, which bear their articulating facets directly upon their under surface. The oblique processes, for articulation with the atlas, have their facets presenting directly outwards; and these are received within the ring of the atlas. The large facet which articulates with the body of the atlas is regularly oval, and quite deeply concave; the odontoid process well developed, convex in every direction upon its articulating aspects, flat on the side which presents toward the spinal canal.

The ring of the *atlas* is large, suboval in shape, its long diameter transverse. Posteriorly, it sends down on either side its slight transverse process, which overlies the anterior extremity of the axis. The fossa for the reception of the single occipital condyle

is semilunar in shape, and very deep. Its concave inner border is formed to a considerable extent by ligaments, which separate it from the depression in which lodges the odontoid process of the axis, and serve to increase the depth of both these depressions. The body of the bone is, on the ventral aspect, prolonged as a spine of inconsiderable size, — the commencement of the ventral series of processes.

Dorsal vertebræ. If we consider the dorsal vertebræ as corresponding in number with the ribs, we should assign ten to this portion of the spinal column. The last three ribs, however, correspond to vertebræ which are completely anchylosed to the sacrum as well as to the iliac bones, and at the same time they differ in several respects from the dorsal ribs proper. It seems more natural, therefore, to consider these ribs as really appertaining to the sacrum, leaving seven to be viewed as true dorsal ribs, — and consequently to consider the number of dorsal vertebræ to be the same.

The transverse processes of these vertebræ are as usual very broad, long, and thin; their posterior borders concave, their anterior convex, and their postero-external angles prolonged backwards into a short "styliform" process, more or less intimately connected with the next succeeding vertebra. The horizontal lamellæ of the transverse processes of the last four vertebræ are pierced by a quite large foramen.

The superior spinous processes of the vertebræ are so long that they nearly touch each other by their anterior and posterior borders; only a slight space being left between them. They are quite regularly rectangular in shape, having straight flat superior borders at right angles with the anterior and posterior borders. They are connected with each other by dense and strong ligaments, and probably become more or less completely anchylosed with age.

The bodies of the dorsal vertebræ present the usual feature of being exceedingly compressed, until they are almost vertical laminæ of bone. But the most interesting feature of this portion of the spinal column is found in the enormous development of the inferior or ventral spinous processes. As the bird must be enabled to dart its neck forward with great power and rapidity, in the capture of its prey, we find these processes, which are the points of origin of the powerful *longi colli*, developed to a corresponding degree. The first ventral process consists of two broad thin laminæ of bone projecting downwards and outwards on either side, divided by a median ridge. These laminæ are sessile on the body of the vertebra. The second, third, and fourth are more peculiar. A compressed pedicle of a length increasing from before backwards, shoots down from the ventral aspect of the body of the vertebra, and bears upon its summit two broad, thin, flat lamellæ of bone, which, divaricating from each other at a very obtuse angle, expand outwards and downwards. These alæ are largest upon the third dorsal vertebra. Upon the fourth they are smaller; and on the fifth, sixth, and seventh become almost atrophied, although the pedicle retains its length. The pedicle of the fifth vertebra is the longest. These ventral processes are well developed on the first sacral vertebra, are merely a minute projection on the second, and totally disappear on the third.

The movements of this portion of the spinal column are exceedingly restricted, and if any exist, they are in a lateral direction. The last cervical vertebra is very freely movable in all directions upon the first dorsal. The last dorsal and first sacral have also perfect articulating facets; but their spinous processes are so extensively anchylosed, that it is probable that but little motion exists between these portions of the spinal column.

Sacral vertebræ. I have been unable to determine the exact number of vertebræ which compose the sacrum. Including the first three costiferous ones, the number is apparently about fifteen. They are throughout completely consolidated with each other, not only by their bodies, but by their processes, especially the dorsal spinous ones. The sacrum thus formed is exceedingly long and remarkably narrow in shape; having a lateral anchylosis with the iliac bones for nearly its whole extent. It is largest and stoutest opposite the acetabula and just posterior to them; where not only the bodies of the vertebræ are enlarged, but the long bony ridge produced by the perfect union of the dorsal spinous processes becomes widened and thickened. This long bony spine has but a slight curvature; so that while just posterior to the acetabula it is scarcely above the level of the iliac bones, yet at both extremities it is elevated some distance above them, by the convexity which their upper border presents. On the ventral surface of the sacrum its first three vertebræ have their bodies laterally compressed, so that a median ridge is produced analogous to that of the dorsal vertebræ. The transverse processes are also tolerably distinct. Just posterior to the acetabula, however, the transverse processes are hardly traceable, and the body of the sacrum has a median longitudinal furrow, instead of a ridge; more posteriorly again, the median ridge reappears, and the transverse processes become evident, intimately joined with the united ilia and ischia, each one separated from the next by an oval foramen.

Coccygeal vertebræ. There are seven bones in the coccyx, all freely movable upon each other. The first two are included between the projecting tubera ischii, which their transverse processes almost touch. Leaving out of consideration the coccygeal vomer, the bones have all the processes of the vertebræ of the other portions of the column. The transverse are largest on the fourth and fifth, becoming smaller both anteriorly and posteriorly. The superior spinous processes are well developed, the more anterior ones terminating by tuberculated extremities, which gradually grow smaller, till the last one is a simple thin lamella of bone. The inferior or ventral processes are rather stout thick tubercles than spinous processes; they are largest posteriorly, and decrease rapidly in size from behind forward.

The "vomer" is of moderate size. Its proximal extremity is deeply concave, bearing in its centre the round articulating facet. The thickening of the bone which forms this facet is continued along the middle of the bone to the extremity, as a prominent longitudinal lateral ridge. The superior border is very thin and sharp, nearly straight in outline; the inferior border curves gently upwards, and is thickened. The distal extremity is simply a small convex nodule, with no projecting process.

Ribs. The ribs are ten in number. Of these nine articulate with the spine, and eight with the sternum. Seven only are dorsal ribs proper; the eighth and ninth being articulated with the sacral vertebræ posterior to the tip of the crista ilii, and the tenth being connected neither with the spine nor sternum.

The determination of the first rib is rendered very easy and certain, by reason of the styliform processes or "rudimentary cervical ribs" decreasing rapidly in length from the cranial to the caudal end of the cervical vertebræ; so that on the last two or three they are merely slight pointed tubercles. Then from the first dorsal vertebræ the first rib projects as a very slender delicate pointed spicula of bone about two inches long, not reaching much more than two thirds the way to the sternum, terminating by a free unattached extremity. This rib is also remarkable for the shortness of its neck, and the consequent close

approximation of its articulations with the body and transverse process of the first dorsal vertebra. In fact there is only left between them a small oval foramen.

The six succeeding ribs are the true dorsal ones, and present the characters of the ribs proper. Their necks are long and slender, and increase in length from before backwards; they support a head which is but very slightly enlarged. The tubercles of the ribs are very large and stout. In fact, these broad, flattened, transverse processes seem almost to form the true termination of the ribs, from which the neck and head proper seem but offsets. The ribs are very flat antero-posteriorly, and scarcely seem to grow narrower as they approach the transverse processes of the vertebræ. But from their inner surfaces there commences, at some distance from the vertebræ, the projecting ridge which is to be continued beyond the transverse processes to form the neck and head.

As usual, the ribs consist of vertebral and sternal portions, movably articulated with each other. Both of these portions grow successively longer from before backwards; but the sternal portions much more rapidly than the vertebral. Thus while the sternal portion of the second rib is barely three fourths of an inch long, that of the seventh is fully three inches. The angle at the junction of these two portions, of course, varies with every stage of an inspiration and expiration; but at any given moment the angles become successively more acute from before backwards, — from the increasing length of the vertebral as well as the sternal portions.

The processes which extend backwards and mesially from the dorsal ribs are well developed, extending not only to the next rib behind, but over it to the succeeding intercostal space. They are not straight, but curved, with their concavities towards the spine. The first one, that on the second rib, is the shortest, stoutest, and straightest; the others become successively longer, slenderer, and more curved, to the penultimate one, but the last one is shorter and smaller than it. These processes are at first only ligamentously joined with the rib, so that they may be easily broken off from the latter; but with advancing age they probably become more or less completely anchylosed. Each process is also connected with the rib from which it arises by a broad, dense, aponeurotic membrane of a triangular shape, extending from its concave border to its own rib, and along the rib to within a short distance of the spine; and with the next succeeding rib by muscular tissue. While each is thus firmly and unyieldingly connected with its own rib, it is enabled to assist the intercostal muscles proper in drawing the succeeding rib towards itself, these slips collectively thus exerting no slight force in the respiratory movements of the thorax.

The two ribs next succeeding the true dorsal, that is, the eighth and ninth pairs, differ from the dorsal in their origin, which is from the sacral vertebræ; and in their great length and tenuity, especially noticeable in their sternal portions, which are very nearly as long as their vertebral. The angle between the two portions is also very acute; but the most important difference is, that with the last dorsal ribs the processes just spoken of abruptly terminate,— so completely that on the ribs under consideration there is not even a rudimentary trace of their existence.

The last rib differs from all the others in being unattached at either vertebral or sternal extremity. It consists merely of two extremely slender elastic bones, tapering to a fine point, somewhat larger and broader at their bases, where they are joined to each other. The sternal portion is longer than the vertebral. Close by the junction of the two, this sternal portion sends off from its posterior border a small, slight process, which curves directly outwards and forwards, lying parallel with the posterior border of the rib, which

it joins again about an inch from its origin, — leaving a space filled up only by membrane. This may very possibly be regarded as the rudiment of an eleventh rib, of which the vertebral portion is wholly wanting. It is sometimes entirely obsolete.

The latter ribs project so far backwards, that the thoracic parietes are prolonged some distance behind the acetabula, and consequently the femur in its normal position lies directly over the last three or four ribs, and moves backwards and forwards upon them. The angle of the last rib reaches within less than two inches of the posterior extremity of the elongated obturator foramen.

Sternum. This bone is sub-rectangular in shape, longer than broad, the greatest length being to the average width as two to one. The length in a direct line from the manubrium to the tip of the xiphoid cartilage is 7.25 inches; width opposite the superior angles, 3.25; width at narrowest part (which is opposite the facet for the sixth rib), 3.00; at widest part (opposite the middle of the apophyses), 3.75. Length of keel along its curved edge, 8.40.

The anterior border is sinuate, projecting at the central line, running backwards as far as the groove for the coracoid bones extends, then turning forwards and outwards to the anterior angle of the bone. Directly on the median line lies the manubrium, in this genus extremely small, merely a slight triangular elevation of bone. The facets for the articulation of the coracoids are very deep sulci, meeting each other on the median line, and extending outwards for two thirds of the width of the bone. The edge of the sternum is thick and strong as far as these grooves extend; externally to them it is merely a thin plane bone supporting the costal facets, forming what are called the "costal processes."

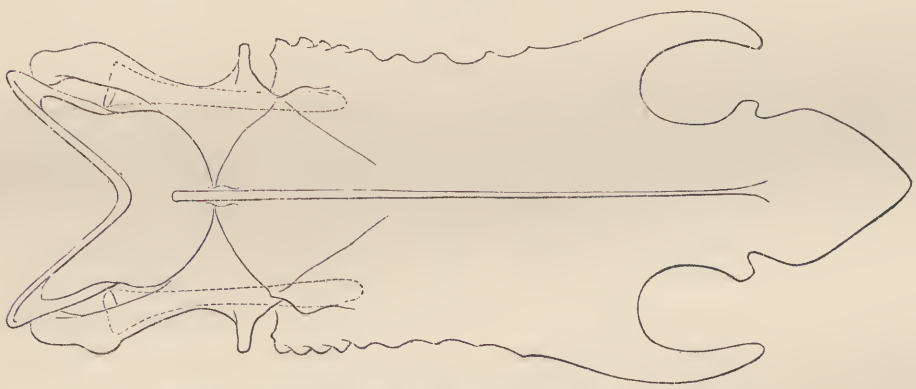
The lateral edge of the sternum measures five inches in length. It is sinuate as regards both a vertical and horizontal plane. It is at first deeply concave, the edge introceding towards the central line; but it bulges out again opposite the base of the lateral apophyses, and then curves again somewhat towards the central line, producing a convex outline. This margin is quite thick anteriorly, but becomes posteriorly exceedingly thin and attenuated. It is marked with articular facets for the sternal ribs; these facets being closely aggregated together anteriorly, becoming much further from each other posteriorly till they cease opposite the base of the lateral apophysis.

The posterior margin is a peculiar one; this arising from the great length and width of the xiphoid appendage, and the depth of the lateral excavations. Considering the posterior margin as beginning with the tips of the lateral apophyses, there is immediately a large elliptical excavation an inch and a quarter deep by nearly an inch broad. Across this is stretched the ordinary dense semi-transparent membrane. Just at the postero-internal border of this excavation there is another notch, but only a very slight one, scarcely a tenth of an inch in depth or width. From the edge of this second notch, the posterior border of the sternum on each side is regularly convex, meeting on the median line by a rounded but somewhat acute angle. This xiphoid appendage is very thin, and curls upwards and backwards from the plane of the sternum.

Posteriorly, the surface of the sternum is very broad and flat, or even slightly concave; anteriorly, it is narrower, and exceedingly concavo-convex, the sides rising upwards from the central portion which is thus caused to bulge downwards, with a very convex surface. The superior surface of the bone is quite smooth and free from inequalities; the inferior surface is marked with various ridges and roughened portions, indicative of the extent of origin of the several pectoral muscles. The most conspicuous of these is a ridge running obliquely backwards and inwards from the outer angle of the coracoid facet.

The keel begins just posterior to the small manubrial process, with a very thick, stout margin, which curves with a concave outline downwards and greatly forwards; so that the apex of the keel, which is quite acute, projects much in front of the anterior border of the sternum. The crest of the keel is regularly a little convex for its anterior half; in the rest of the length it is almost perfectly straight, to its subsidence into the level of the surface of the bone, which takes place just at the base of the xiphoid. The crest of the keel is broader than the vertical portion, and, with the latter, is rough for the attachment of the pectoral muscles. The vertical depth of the keel is, just at its anterior extremity, very considerable, being nearly one and a half inches; but very quickly, by the great

Sternum and scapular arch *in situ*, lateral view, one half natural size.
(Figure 1.)



Sternum and scapular arch *in situ*, from below, one half natural size.
(Figure 2.)

downward projection of the body of the bone, joined with the slight convexity of the crest of the keel itself, it becomes inconsiderable, and then more gradually decreases as it proceeds backwards.

Viewing, now, the sternum as a whole, we have to notice how great an extent of surface is secured with a trifling increase of weight. Posteriorly, this is attained by means of the great lateral projection of the apophyses, as well as by their length, and by the breadth and projection backwards of the thin, almost cartilaginous xiphoid. Anteriorly, where the sternum is not so wide, the deficiency is atoned for by the great depth of the keel, and

its projection forward; at the same time the outline of the crest of the keel is such that when the inequalities of the bone are all filled up with muscular tissue the resulting surface becomes flat, and broad as well as long, affording the best possible outline for contact with the water.

Coracoids. These are very short, and exceedingly broad and stout. Each measures just three inches in extreme length. The "shaft" proper of the bone is reduced to a minimum of length, nearly the whole bone being taken up by the articular and other processes at the base and head.

The base of the bone is expanded into a broad, flat, trapezoidal surface, the sides of the trapezoid being all more or less concave. The postero-internal side is concave, smooth, and thin, fitting accurately into the articular groove in the sternum. The antero-internal border is simply a concave outline, running forward to become the inner edge of the shaft of the bone. The antero- and postero-external borders of the trapezoid are the most concave of all, being formed by a quite acute process of bone which runs directly outwards exactly under the costal process of the sternum.

On the inner aspect of the shaft of the bone, just internal to the coraco-scapular articulation, there is a lateral expansion of the bone, which curves upwards and forms the pulley over which glides the tendon of the pectoralis minor, in its passage to its insertion into the head of the humerus. This lateral expansion forms by its superior surface a good part of the coraco-scapular articulation. Its inner tip forms a little of the superior coraco-clavicular articulation.

On the shaft of the bone inferiorly there extends downward towards its head a stout thick ridge terminating in a convex, somewhat oval process, which bears upon its inner face a semilunar facet for the inferior or principal coraco-clavicular articulation. The external and superior aspect of the bone has a flat broad dilatation terminating in a convex facet lined with interarticular fibro-cartilage, forming the inferior half of the glenoid cavity. Upon the superior aspect of the shaft, just internal to the preceding facet, there is the somewhat semilunar facet for the coraco-scapular articulation.

Clavicles. These bones are altogether weaker, and meet at a more acute angle, than we should expect to find in a bird possessed of the powers of flight of the Loon. The angle formed by their divergence is scarcely more than 45°. At their broadest part, which is near their origins, they are over half an inch wide, but exceedingly thin. This width decreases rapidly towards the symphysis, where the bones are very weak and slender, and oval or elliptical on a transverse section. The symphysis is a simple fusion of the two clavicles, without any projecting lamella or process, and unconnected except ligamentously with the apex of the sternal keel. Each of these bones articulates in two places with the coracoids, as has been already pointed out. From these articulations the bones when *in situ* dip at first directly downwards, then with a very convex outline run backwards, at last curving upwards again to the symphysis with a considerable degree of convexity. From the peculiar articulation of these bones with the coracoids at two points it results that the curved surface which serves as a pulley for the play of the tendon of the pectoralis minor is converted into a complete bony canal.

Besides the proper articulation of these bones with the coracoids, they are throughout their whole extent bound to the latter by a dense layer of fascia, the supraclavicular, which is stretched vertically between the bones.

Scapula. The scapula, as in most birds, is simply a long, narrow, flattish bone, lying

superimposed upon the dorsal aspect of the ribs, nearly parallel with the vertebræ, and situate somewhat more than an inch from them. It measures 3.60 inches in length, by about one fourth of an inch at its lower, and three fourths at its upper or broadest end. It is concavo-convex in two planes: *i. e.*, slightly so in the horizontal plane, its convex edge being presented towards the vertebræ; and much more decidedly so in a vertical plane, the convexity presenting upwards. In the greater portion of its length the transverse section of the bone is elliptical or oval; but towards the distal extremity it becomes depressed into a simple thin flat lamina. This lamina is nearly straight and very thin, and forms the termination of the scapula without curving in any direction. The proximal extremity of the bone is much thicker and stronger than the rest. It bends downwards with a very considerable, and inwards with a slighter, curve. The thick head of the bone, thus constituted, articulates with three bones, — the clavicle, coracoid, and humerus.

The claviculo-scapular articulation is a mere apposition of the extreme apex of the clavicle with a very small space just at the internal edge of the head of the scapula, where that edge projects inwards upon the expanded lateral process of the coracoid, which forms most of the second or superior coraco-clavicular articulation.

The coraco-scapular articulation is an exceedingly strong and firm apposition of the whole head of the scapula with the rough depression on the superior surface of the shaft of the bone, just internal and posterior to the glenoid cavity. The articulation seems to be essentially almost a synchondrosis. The rough inequalities of the head of one bone are perfectly coaptated to those of the other; interarticular fibro-cartilage is interposed; and the whole articulation is so firm and unyielding as to permit of but exceedingly limited motion, and that chiefly in one direction. That part which the scapula takes in the formation of the glenoid cavity constitutes the humero-scapular articulation. The glenoid cavity merits special notice.

When the glenoid facets of the coracoid and scapula are deprived of the dense layer of fibro-cartilage which chiefly forms the concavity in which the head of the humerus plays, they are found to be perfectly smooth and plane. Both are tolerably regularly oval in shape, the coracoid the larger, and quite oval, the scapular smaller, and more of an elongated and subtriangular shape. The coracoid facet is horizontal antero-posteriorly, with transversely an obliquity of about 45° upwards and outwards; the scapular is about perpendicular to it, with transversely 45° of obliquity forwards and outwards. Upon this osseous basis a very dense and thick layer of unyielding fibro-cartilage is superimposed, to form the slight concavity which exists for the reception of the head of the humerus. This cartilage is laid over the whole of both facets, but is much the thickest at their margins, where it rises with a well-defined edge, leaving a central depression which constitutes the true glenoid "cavity." This cavity is very broadly semilunar in shape, the cornua of the semilune having quite well-defined, raised borders, its convexity being but slightly, and its concavity scarcely at all, elevated. But the depression is so slight that the entire cavity is able to contain but a comparatively small portion of the articular head of the humerus. This disposition of the elements of the articulation, as well as the shape of the head of the humerus, is plainly indicative of the design of the joint, — the attainment of great freedom of motion in all directions by some sacrifice of strength. A comparison of the glenoid with the cotyloid cavities of this bird furnishes a striking illustration of the preponderance of *mobility* over *stability* which usually obtains in the anterior extremities of the higher vertebrates.

The disposition of the fibro-cartilage above noticed, by which the glenoid cavity is augmented in depth, is strictly homologous with the raised border of cartilage which surrounds the same cavity in man, and which subserves the same purpose. The same plan, according to Owen,[1] exists throughout the lower orders of birds, the *Rasores*, *Natatores*, and *Grallatores;* while in the more highly organized birds, the *Raptores* and *Insessores*, there is found a distinct bone, the "*os scapulare*," or "*os humero-scapulare*," which subserves the same purpose.

Humerus. This bone is moderately long for the size of the bird, but quite stout and strong, and especially notable for the extensive development of the crests and processes near its proximal extremity. It measures between seven and a quarter and seven and a half inches in extreme length. The shaft is centrally very nearly circular on a section; towards both extremities of the bone it soon becomes flattened in a plane about half-way between the vertical and horizontal,—at the distal extremity to form the two condyles; at the proximal, to expand into the well-marked superior and inferior crests. The superior crest is very high and long, extending from the articular head to beyond the middle of the bone before it is obliterated; but it is only conspicuously elevated for about one and a half inches of its length, for the greater part of which extent it affords attachment to the broad tendon of the great pectoral. Mesial to this crest, on the shaft of the bone, about an inch from the head, is the small tubercle for the attachment of the conjoined tendinous slips from the latissimus dorsi and the long extensor cubiti. The inferior crest curves as usual in the opposite direction from the superior. It is much shorter, broader, and thicker than the superior, and is placed obliquely to the shaft of the bone, that is to say, parallel with the inward inflexion of the proximal end of the shaft towards the glenoid cavity. Its under surface presents well marked the ordinary deep fossa; its superior surface near the articular head of the bone also another fossa, more shallow, however, than the inferior. The proximal extremities of both of these crests are marked with several tubercles and facets for the insertion of various muscles, the majority of all the muscles which act upon the humerus being inserted into one or the other of them.

Between the proximal extremities of these crests is situate the articular head of the bone. It is of an oval shape, exceedingly convex in its transverse, less so in its longitudinal axis. Its face is placed obliquely with reference to the shaft of the bone, from the fact of that part of the bone which supports it curving inwards to meet the glenoid cavity. Its long axis, which is placed directly between the extremities of the superior and inferior crests, is not quite vertical, but inclines obliquely outwards and upwards. The nature of its connection with, and movements in, the glenoid cavity, have already been adverted to.

The distal extremity of the bone presents well marked the great peculiarity which characterizes the elbow-joint of the class *Aves;* namely, the hemispherical tubercle for the ulnar articulation, and the elongated oblique tubercle, extending somewhat along the shaft of the bone, over which the radius moves. The necessity for the very peculiar shape of these articulating facets arises from the obliquity of their plane in relation to the plane of the circle which the ulna and radius describe in the unfolding of the wing. The articular facets do not project directly outwards, but obliquely downwards and outwards, so that, in the folded wing, the distal extremities of the ulna and radius are below the level of and external to the proximal extremity of the humerus. Now, in extension of the forearm, by the peculiar motion which the radius has over the elongated oblique tubercle with which

[1] In Todd's *Cyclopædia of Anatomy and Physiology*, Article *Aves*.

it articulates, its distal extremity describes a greater arc of a circle than does that of the ulna; so that, although the plane of the circle in which these bones move is oblique to the axis of the humerus, yet during extension this obliquity becomes gradually less and less, until at full extension it quite disappears, and the bones of the arm and forearm lie in the same plane.

It is exceedingly interesting to compare this articulation with the elbow-joint in the human species. In the latter, the connection between the ulna and humerus is most strictly ginglymoid, admitting of only backward and forward motion; while pronation and supination are perfect, by the very free rotation of the radius upon the outer tuberosity of the humerus, and around the distal extremity of the ulna; but the radius also has, in common with the ulna, the ordinary ginglymoid movements of flexion and extension. Thus the elbow-joint, taken as a whole, and considered with reference to the movement of the forearm upon the arm, is strictly a ginglymus, notwithstanding the element of the *diarthrosis rotatorius* of the head of the radius. In birds, although pronator and supinator muscles exist, yet they seem to serve rather to steady the radius than to move it, and the pronation and supination of the forearm is exceedingly limited, if indeed it exist at all. While, therefore, the axes of the two bones of the forearm scarcely change their relations to each other, the common plane of their two axes is continually changing its relation to the axis of the humerus, in flexion and extension of the forearm. This peculiar character of the movements of the forearm is arrived at by the complete obliteration of the element of *rotation* in the humero-radial articulation, and the conversion of the direct antero-posterior ginglymoid motion into an oblique ginglymus. As the ulna must of course accompany the radius in this obliquity of its flexion and extension, the deep sigmoid cavity is converted into a shallow circular depression, which receives the small hemispherical articulating facet of the humerus. By this means it can adapt its motions to any degree of obliquity which may be impressed upon it by the position of the radial articulating surface.

Another interesting feature in this joint is that it is not the head of the radius alone which articulates with the radial facet of the humerus. That part of the head of the ulna which lies immediately above and posterior to the radio-ulnar also plays over this outer oblique tuberosity of the humerus, forming with the rounded head of the radius an elongated depression, which accommodates itself to this elongated radial facet. In this feature of the articulation of the head of the principal bone of a limb with *both* the condyles of the bone above it, is seen an indication of what exists in the femoro-tibial articulation of the human species; and since it seems to denote a tendency of the element of stability to preponderate over that of mobility, it is what we might expect to find when we remember how fixed the radius is to the ulna, causing the motion of the forearm to be limited to flexion and extension.

The posterior aspect of the end of the bone presents two well-marked longitudinal grooves, completely separated from each other by a median ridge. These grooves give passage to the tendons of the two extensor muscles of the forearm, proceeding to be inserted respectively into the outer and inner sides of the olecranon. The olecranonoid depression is hardly recognizable as such; and the coronoid is but slightly marked.

Ulna. As usual, much larger throughout its whole extent than the radius, and quite as large at its distal as at its proximal extremity. It is a little less than six inches long. Its shaft is considerably curved in its whole length, subcircular on section, being flattened

along its inner aspect. Its external border is marked by oblique ridges corresponding to the insertions of the secondary quills. The olecranon is a somewhat compressed process at the posterior aspect of the head of the bone, but does not extend above the margins of the articular cavity. This latter is placed upon the inner and anterior aspect of the head of the bone, and has been already described. Just external to, and below it, is the radio-ulnar articulation. It is merely a slight subtriangular depression, against which the head of the radius is apposed, and has leading from its superior margin the continuation of the facet on the head of the radius, for articulation with the external oblique tuberosity of the humerus. Both lateral surfaces of the head of the ulna are rough, for the attachment of muscles.

The distal extremity of the ulna is fully as large as the proximal, but of quite a different shape. It is greatly flattened horizontally, the anterior margin projecting forwards as a flat ridge, over the superior surface of which passes the radius. The articulation of the radius with the ulna is however merely by a small facet on the middle of this superior aspect of the head of the bone. The greater part of the remaining surface of the head of the bone forms a smooth, somewhat semilunar depression, by which it is articulated, partly with the posterior half of the head of the metacarpal bone, and partly with the small carpal bone, as is more particularly described further on.

Radius. The radius is exactly of the same length as the ulna, but much smaller than it throughout its whole extent. It is quite straight except just at its distal extremity, where it is somewhat decurved to overlap the extremity of the ulna. Towards its lower extremity it increases in size, though not to any great degree, and becomes horizontally flattened. Its rounded head, considerably larger than the shaft below it, bears upon its inferior border the small ulnar articulating facet, and upon its face the much larger and somewhat oval depression for articulation with the humerus. Its distal extremity is marked superiorly with a very deep groove, which continues for some distance up the shaft for the lodgment of the tendon of the extensor metacarpi radialis. Just internal to it is another groove, but much shorter and less conspicuous.

The radius articulates below with the ulna, as already described; but its principal articulation is with the large bone of the carpus. Nearly the whole of its extremity is occupied by an oval facet, long in its horizontal diameter and transversely very convex, which is received into the deep concavity on the radial aspect of the carpal bone. This radio-carpal articulation presents just the opposite feature from that of man, a convexity of the end of the radius being received into a concavity in the carpal bone, instead of the reverse.

Bones of the Carpus. Of the two carpal bones, that corresponding to the scaphoid, semilunar, and cuneiform, is the largest, and articulates chiefly with the radius. It is wedged in at the outer angle of the joint between the metacarpal bone and the radius, extending far enough towards the ulnar side of the joint to articulate with the ulna by a small facet. It is of a very irregular shape, marked with three facets, for articulation respectively with the radius, ulna, and metacarpus, and with two deep grooves for the lodgement of tendons.

The deep radial facet has been already noticed. Just on the opposite side from it, the face of the bone presents the smooth depression for the reception of the head of the metacarpus; this facet is divided into two parts by a vertical median ridge, corresponding to the vertical depression in the head of the metacarpus. The very small facet upon the interno-posterior aspect of the bone articulates with the radial edge of the large terminal facet of the ulna.

Upon the superior surface of the bone there runs longitudinally the continuation of the deep groove of the radius which lodges the extensor metacarpi radialis. At right angles with this and running transversely, there is a still deeper groove which conducts the tendon of the flexor metacarpi radialis.

The second, smaller bone of the carpus, which represents the second row of carpal bones, is placed just in the bend of the joint, on the ulnar side, wedged in between the ulna and metacarpus, with both of which it articulates. Its ulnar aspect presents a smooth, oval, somewhat depressed facet, which plays against the extremity of the large articulating surface of the ulna. Its metacarpal aspect presents a very deep horizontal notch or fissure, into which is received the inferior thin border of the metacarpal bone. In flexion and extension of the metacarpus, this small bone rides backwards and forwards along the edge of the metacarpal bone, being as it were astride of the latter. The non-articular aspects of the bone are rough for the attachment of tendons.

Metacarpus. In the single metacarpal bone, which, as in all birds, results from the fusion of the five of the human species, there may be clearly traced three distinct bones.

The first, which corresponds to the metacarpal of the thumb, is found superimposed upon the radial edge of the metacarpus, and intimately blended with it, appearing like an elevated crest. It is about one and a half inches long, and bears upon its distal extremity the pollex or thumb.

The second, or metacarpal of the little finger, lies directly upon the ulnar side of the bone, and is much more distinct than the preceding. It is from its origin for about half an inch, fused with the main bone, but then becomes entirely separated from the latter by a considerable hiatus, running forward to be again united to it about half an inch from its distal extremity. It supports upon its tip the "ulnar finger."

The remaining greater portion of the metacarpus results from the coalescence of the three middle bones of the human hand. This supports the three phalanges of the "radial finger," and articulates with the radius and ulna.

The metacarpus, thus constituted, is a strong bone, nearly four inches long by about five eighths of an inch broad at the broadest part, much compressed. Its proximal extremity is taken up wholly by a single large, smooth, articulating facet, which moves upon the ulna and both of the carpal bones, but has no connection with the radius, the large carpal bone being interposed between it and the head of the latter. This articulating surface is exceedingly convex from the radial to the ulnar side; but presents in the median line a deep sulcus running its whole length, causing the transverse outline of the head to be concave. The greater part of the head is joined by a strictly ginglymoid articulation to the central portion of the large facet on the ulna. At the radial side the articulation is with the large carpal bone; at the ulnar, the inferior border is prolonged backwards, and forms the prominent ridge over which rides the smaller carpal bone, as already described. On either side of the articulating surface the bone presents rough elevations and depressions for the insertion of tendons and ligaments. On its superior aspect the bone is also marked with several longitudinal grooves, which lodge the tendons that are inserted into the phalanges.

Phalanges. The pollex, or thumb, is a short, perfectly straight bone, which projects one inch beyond the abrupt termination of the crest-like elevation corresponding to the first metacarpal bone. It is much compressed laterally, and terminates in a truncated sharp edge. It is movably articulated with the metacarpal bone, but really has but very slight motion.

The third or "ulnar finger" is a single short, slight phalanx, about half an inch long. It proceeds from the extremity of the ulnar metacarpal, with which it is articulated, but is so firmly bound by ligaments to the under edge of the first phalanx of the larger radial finger that it enjoys little or no motion.

The middle or "radial finger" forms the proper continuation of the hand. It consists of three phalanges. The first is of considerable size, being one and a quarter inches long, its radial side thick and flat, and separated by quite distinct borders from the thin lamelloid expansion on its ulnar aspect. Its proximal end articulates with the distal extremity of the metacarpus by a slightly depressed and irregular surface. The second phalanx is much smaller, though of about the same length as the preceding, from which it differs chiefly in not having the compressed lamella of bone proceeding from its ulnar aspect. It articulates with the preceding by an enlarged head. The third phalanx is merely a very small, insignificant, acutely pointed spicula of bone, scarcely a third of an inch long.

Ossa innominata. The innominate bones are remarkable for their great length antero-posteriorly, as well as for their extreme narrowness and the straightness of their longitudinal axis, which latter is scarcely more curved than is that of the sacrum itself. They measure, from the tip of the ilium to the tuberosity of the ischium, six and a half inches; and they extend from the interspace between the sixth and seventh ribs to that between the second and third coccygeal vertebræ. Throughout this extent, they are very closely apposed to, and lie parallel with, the spine; and they are completely anchylosed with it, except for about half an inch at each extremity. Besides the want of antero-posterior curvature, the bones — leaving out of consideration the rami of the pubes, which are curved towards each other on the median line — have little or no lateral convexity. They converge towards each other on the spine, at an angle of about 50°, forming a greatly elongated, very narrow pelvis; which, by the flattened shape of the ischia is quite deep and transversely triangular posteriorly, but which, more anteriorly, by the termination of the pubes at the acetabula, and the outward expansion of the ilia, becomes so shallow as quite to lose its characteristics as a "cavity." On the median line, the ilia, as usual in the class, do not meet, but are throughout separated by the anchylosed spinous processes of the sacral vertebræ. The approximation of the two cristæ ilii is greatest just posterior to the ischiadic foramen; both anterior and posterior to this point the bones slightly recede from the median line of the vertebræ, the amount of divergence gradually increasing, until the tips of the ilia are three fourths of an inch, and the tubera ischii one half an inch, from the median line.

Ilium. This portion of the os innominatum is, anteriorly to the acetabulum, a very thin, narrow, osseous prolongation, extending forwards and a little outwards as far as the seventh rib. It is externally concave antero-posteriorly, and also laterally very slightly so. It is completely anchylosed, to within less than one half an inch of the tip, with the transverse processes of the sacral vertebræ over which it is imposed. It has no connection, however, with the last ribs, though these pass out so close beneath it that they almost touch its internal surface. Towards the acetabulum the bone spreads out as a stout curve, which meets a similar projection from the ischio-pubic bone, and then completes the circle of the acetabulum. Just above the ring, the acetabulum proper, the bone becomes very thick and strong, and is elevated into a projection which overhangs as it were the cotyloid cavity. This eminence is suboval in shape; and bears upon its summit a flat, smooth, articular facet, continuous with the articular surface of the acetabulum proper, to which is

apposed the superior surface of the trochanter major of the femur. The ilium posterior to the cotyloid cavity continues along the spine as a simple prolongation of bone for about an inch, after which it is completely fused with the ischium for the rest of its extent. The ordinary ischiatic notch of man is thus converted into a foramen. The foramen in this instance is of an oval shape, three fourths of an inch long, by one third in diameter, lying mesially to the obturator foramen at its commencement, just posterior to the cotyle, and close to the spine.

Ischium. The ischium is quite flat, scarcely presenting a concavity or convexity in any direction. Its mesial border is completely fused with the ilium, except anteriorly where it separates from that bone to form the ischiatic foramen, and runs forward as a slender process, separating the ischiatic from the obturator foramen, to the acetabulum, which as usual it assists in forming. Posteriorly, the bone is prolonged, forming quite a long and narrow but stout process, terminating in the tuber ischii, lying close alongside of the transverse processes of the two first coccygeal vertebræ, but not united with them. Between this projection and the process which curves forwards and outwards to meet the pubes there is a deep semilunar sulcus. The external border of the bone is long and concave, the latter especially at its extremities, — this concave border forming the mesial margin of the obturator foramen.

Os pubis. This is a long and exceedingly slender bone. Its anterior extremity, which contributes its share in the formation of the acetabulum, is tolerably broad and strong; but the bone immediately becomes contracted to a slender straight spiculum, which extends between the acetabulum and the projecting process of the ischium, forming the external border of the obturator foramen. With the tip of this projecting process, which seems to represent in part at least our "ascending ramus of the pubes," the bone is movably connected by ligaments. From this point the bone curves quite abruptly mesiad to meet its fellow. It becomes at the same time broad and thin, the breadth increasing suddenly towards the end, so that the bone terminates by a wide, rounded, club-shaped free extremity. As usual in the class, there is no symphysis pubis, though the two bones closely approach each other.

The shape and position, as well as the connections of the os pubis with the rest of the pelvis, are such that the free extremities of the bone must be approximated or separated chiefly by the *elasticity of torsion* of the slender shaft of the bone.

Acetabulum. The acetabulum has quite lost its character as a "cotyloid cavity," and become a simple ring of bone. The floor of the cavity is so entirely wanting, that the internal diameter of the acetabular ring is nearly as great as the external. The outer border of the ring is a well-defined, elevated osseous ridge,—most marked posteriorly and externally, but sinking somewhat towards the mesial line. The globular head of the femur is prevented from sinking through this ring by the abutment and articulation of its trochanter major with the prominent facet already described as lying above the cotyle. The smooth articular surface of the acetabulum is continued uninterruptedly on to this facet, so that the articulation of the head and trochanter of the femur is really only a single joint. The exact character of the motions resulting from this joint will be described in speaking of the femur.

Of the Lower Extremities.

In the upper extremities of the bird, although there is much interesting mechanism displayed, yet the various features are in general only such as are found in the wings of the greater number of the groups of the order. The very peculiar type of structure which stamps such an individuality upon the *Colymbidæ*, *Podicipidæ*, and, to a somewhat less extent, upon the brachypterous *Natatores* generally, does not extend in any very marked degree into the superior extremities. It is in the morphology of the posterior extremities, both as regards the osseous framework and the muscles by which the bones are moved, that we find the most marked peculiarities of structure. When we recollect how very peculiar are the form and position of the posterior extremities, both as regards the axis of the bird's body, and its centre of gravity, causing progression on land to be awkward and laborious from the stiff and constrained position in which the body must be placed to bring the centre of gravity within the base of support, we might naturally expect to find interesting peculiarities in the structure of these extremities. Such is really the case; the whole morphology of the posterior limbs being so moulded as to obtain the most advantageous structure possible for propelling the bird over and through the water, at a considerable sacrifice of ease and power of terrestrial locomotion.

This indication, which we see more or less completely fulfilled throughout the *Natatores brachypteri*, is perhaps more strongly pronounced among the *Colymbidæ* than in any other family of birds, with the exception of course of the Penguins, (*Aptenodytes*, *Spheniscus*, &c.,) and certainly reaches the maximum of development which is found among any birds that retain the power of aërial locomotion. The species of bird now under consideration being typical, so to speak, of the whole family, in it we can study this peculiar type of structure to great advantage.

In examining the morphology and functions of the lower extremities, we must of course consider them with reference to their action upon that element to which they are specially adapted, — the water. To produce a perfect pair of paddles, three indications must be fulfilled. First, the limbs must be articulated far backwards, and, while they have the freest motion, must be so abducted from the median line that the broad webs shall not interfere with each other. Secondly, in the backward stroke the broadest possible surface must be attained for action upon the water, while in bringing the leg forward exactly the reverse must be the case. Thirdly, the great power of the legs must be chiefly exerted in *pushing;* and hence the bulk of the muscles must be upon the posterior aspect of the several components of the legs. The mode in which this latter indication is fulfilled will be noticed in the description of the muscles. The first two may here be considered.

Femur. This bone is remarkably short and stout. It measures only two inches in entire length, while across the condyles it is three fourths of an inch, or more than a quarter of its total length. The width across the upper extremity, from the trochanter to the globular head, is fully half an inch. The shaft is also exceedingly stout, and much curved, the convexity presenting forward. It is marked along the entire length of its posterior aspect, as well as over the trochanter and on the sides of the condyles, with roughened tubercles and depressions for the attachment of the various muscles which act upon it.

The globular "caput femoris" is peculiar both in shape and position. It projects almost

at right angles from the inner aspect of the proximal extremity of the bone. The neck, however, is so very short and thick, and projects so directly inwards, that the head appears to be little more than a stout process of bone. It is, moreover, placed so low down on the femur, that the great trochanter rises very considerably above its level. Its summit is as usual occupied by a fossa for the insertion of the ligamentum teres.

The trochanter extends upwards and outwards as a stout, somewhat pointed process, and is so large as to seem to form the real "head" of the bone; from the inner aspect of it the real head appears as a short stout offset. The non-articular surfaces of the trochanter are all roughened for the attachment of muscles. There is no trochanter minor.

The hip-joint is an exceedingly peculiar and interesting one, from the extent of the trochanteric articulation. The smooth articulating surface of the globular head of the bone is on the superior aspect continued uninterruptedly along the neck of the femur, to spread out on the top of the trochanter into a large, smooth, plane facet, which occupies nearly all the superior surface of that process.

When the head of the bone is inserted into the circular ring which constitutes the acetabulum, this articulating surface of the trochanter is applied closely to the smooth facet which, as already described, lies above and a little behind the acetabulum, appearing like a continuation from it, which in effect it really is. This abutment of the trochanter against the ilium prevents the small head of the bone from sinking too deep into the cotyle, which it would otherwise do from the very deficient character of this cavity; and, moreover, upon it seems to be borne the chief pressure of the weight of the body in some of its attitudes.

From this peculiar construction of the hip-joint, it results that a particular direction is given to the position, and all movements of the femur, and that motion in some directions must be exceedingly free, while in others it is greatly restricted, or wholly arrested. From the direction in which the plane of the trochanteric facet is situated, it results that the most natural and unconstrained position of the femur is outwards, forwards, and downwards, at an angle of about 45° in each of these axes. This remarkable outward position, or great amount of abduction, is necessary to enable the femur to clear the long ribs which project outwards and backwards along its inner aspect, and also contributes its share towards the wide separation of the feet. From this state of permanent abduction, any adduction, or any further abduction, are equally impossible; for the first would draw away the trochanter directly from its articulation, the latter would pull the globular head directly out of the cotyloid ring. Therefore, though muscles exist which arise from the horizontal ramus of the pubes and are inserted into the femur at various points, and which are really the analogues of our pectineus, adductors, etc., still, their line of traction, resulting from the shape of the pelvis and position of the femur, is such that they pull it almost directly backwards, having little if any adducting power.

Antero-posteriorly, the normal position of the femur seems to be in a state of semi-flexion forward at an angle of about 45°, with of course the divergence downwards and outwards before mentioned. From this position the movements of flexion and extension are quite free, the former particularly so.

The element of *rotation* is a very prominent one in the motions of the hip-joint, affording, as we shall presently see, the beginning of the very extensive power of rotation which the whole limb enjoys. A special muscle, the obturator, inserted into the tip of the trochanter,

would seem to preside especially over the outward rotation; besides which various flexors, extensors, glutæi, etc., are made to act either as external or internal rotators, by some peculiarity in their insertion into the femur.

In the positions and movements of the femur we see its perfect adaptation to the functions it has to perform, — those of affording a short, stout *point d'appui* for the leg, at a sufficient distance from the body, and of powerfully impressing upon the distal segments of the lower extremity antero-posterior and rotatory motions; this *force* of motion decreasing as we proceed from the body just in proportion as *extent* of motion is augmented. It would not seem that the length of the first segment of a limb is an indication of the powers of that extremity. Thus among the *Cypselidæ* and the *Trochilidæ*, whose powers of flight are unsurpassed, the humerus is very short; but in them, as in the case before us of the Loon's femur, the primary segment is most powerfully acted upon by large muscles, which force of motion is by a common law of mechanics converted by the long distal segments into extent and rapidity of motion.

The distal extremity of the femur is no less interesting than the proximal. The shape of the two condyles, as well as of the articulating surfaces themselves, is very different. The external condyle is very much the larger of the two, projecting more outwards and as much further downwards than the internal one, as from the obliquity of the femur it is necessary to bring the faces of the two upon the same plane.[1] Its articulating surface is longitudinally very convex, transversely equally concave, by a rounded sulcus, which causes its convexity to present a ridge on each side. This is the true articular surface of the outer condyle, and it is closely coaptated with the head of the fibula. Upon the internal side of the condyle there is also, however, a facet of an oval shape, which articulates with a corresponding facet on the fibular edge of the head of the tibia. The proper femoro-tibial articulation is however with the internal condyle. The latter is much less irregular than the outer one, having simply an oval extremity, convex in both its axes, which rests upon the very slightly depressed, broad, flat head of the tibia. The movements of the knee-joint will be spoken of after noticing the bones of the leg.

Tibia. This bone is very long, measuring with its spine seven and a half inches, and consequently containing the length of the femur nearly four times. Its spine is just two inches long, leaving a length of five and a half inches for the tibia proper. Below, it is flattened antero-posteriorly, indicating its further expansion into the two condyles ("malleoli"). More superiorly, it becomes sub-quadrilateral. The outer posterior edge forms for nearly its whole extent the fibular anchylosis. The inner anterior edge is the most prominent. About one and a half inches below the head of the bone it rises as a very prominent thin crest, with a sharp margin. This crest curls over forwards more and more, until it has on its anterior aspect a deep longitudinal concavity, and, preserving much this shape, is prolonged two inches above the head of the bone as an exceedingly prominent spine. The posterior aspect of this spine is at its base prolonged directly from the articular head of the bone, forming a deeply concave continuation of the joint, exactly resembling the olecranon of the human species.[2] Indeed, this articulating surface of the tibia has almost exactly the shape and general appearance of the sigmoid cavity of our ulna. The

[1] Prof. Owen considers our olecranon to be not a patella joined to the ulna, but as rather analogous to the structure we are now considering.

[2] This difference in the length of the two condyles, to atone for the obliquity of the shaft of the femur, is precisely upon the same principle as in man, but the case is exactly reversed, — since, as the femur is permanently abducted, instead of adducted, the outer condyle instead of the inner must be the longest.

entire surface of the spine presents roughened elevations and depressions for the attachment of muscles. The oval concave head of the fibula, placed on the external aspect, completes the crural elements of the knee-joint.

Just at the superior border of the joint there is a very small projecting process of bone, which is generally regarded as the true analogue of the patella.

The twofold design of this elongated spine is quite evident. In the first place, by the simplest mechanical law, it increases greatly the power of the extensor muscle, the cruræus, coming down over the front of the femur. Secondly, some of the most powerful of the muscles which act upon the metatarsus take their origin primarily from its extreme tip, and the consequent increased length of fleshy bellies which they thus acquire gives them an equal increase of space for contraction.

The construction and movement of the knee-joint present several interesting peculiarities. Although both condyles of the femur articulate with the tibia, the most extensive articulation of the outer one is with the head of the fibula, upon which it principally rests. In this bird, however, while flexion and extension of course form the most prominent elements in the motion of the leg upon the thigh, to these there is superadded a very considerable degree of true rotatory motion, also quite different from the peculiar obliquity of motion which obtains in the elbow-joint.

The ordinary position of the leg, with reference to the axis of the body, when least influenced by muscular action, is to lie not very far from horizontally backwards, with some degree of inclination downwards, and a greater amount of obliquity outwards. When the leg is strongly flexed, it results, from the peculiar direction of the femur from the body and from the plane of the femoral condyles, that the leg becomes quite parallel with the axis of the body, while its outward inclination is totally lost. The legs in a fresh specimen may be easily made to touch each other over the coccygeal vertebræ. Conversely, with strong extension, the axis of the leg becomes more and more nearly perpendicular to the axis of the spine, while its amount of abduction from the body is constantly augmented. These are the positions consequent upon simple flexion and extension.

In the ordinary semi-flexed position of the leg, the plane of the condyles with which the metatarsus articulates, is placed obliquely outwards instead of directly forwards, so that the metatarsus projects outwards from the body; and the fibula, especially at its upper part, is rather upon the posterior than the directly external aspect of the leg. Now, when the leg is drawn forwards, the same muscles are so inserted that they cause a rotatory motion (chiefly in the knee-joint), which brings the fibula directly outwards, the plane of the tibial condyles directly forwards, — and consequently the sharp anterior edge of the metatarsus, and the anterior surface of the closed toes, cut easily through the water, with but slight resistance.

Although the femur participates in this rotatory motion of the lower extremities, yet the rotation is still greater in the knee-joint. From the construction of the joint, — remembering the broad flat head of the tibia on which the convex internal condyle rests, and the much more intimate coaptation of the head of the fibula with the external condyle, — it seems probable that the extremity of the fibula is chiefly the pivot around which the motion of the knee-joint takes place. Several muscles of the leg seem to act solely as rotators, while many of the flexors and extensors are so inserted as to have some such action.

The two condyles at the distal extremity of the tibia forming the "malleoli," are very

prominent and convex, with a deep sulcus between them. They much resemble, in general appearance, the condyles of the human femur; but are laterally more compressed, and the sulcus between them is wider. It is remarkable that the internal one is the largest and longest, so that the obliquity of the tibia in relation to the axis of the body, instead of being corrected in the metatarsus, is increased, and the foot thrown still further outwards. On the posterior aspect, the condyles continue upwards for some distance, as prominent narrow ridges, serving to confine the very numerous tendons which pass down over the heel. The sides of the condyles are rough for ligamentous attachment. Just above the condyles, on the anterior face of the bone, is the depression ordinarily met with, crossed by a very distinct though small bridge of bone, forming a canal through which the extensor tendon of the toes passes.

Fibula. This is as usual a tapering bone, not extending the whole length of the tibia, and attached to its outer and somewhat posterior aspect. Its head is quite distinct, lying just at the edge of the head of the tibia, receiving the greater part of the outer condyle of the femur. For an inch or so, it is quite separate from the tibia; is then united with it for some distance, becomes again distinct for about an inch, and then finally merges as a slender spiculum into the side of the tibia, rather more than an inch above the joint. A slight crest, however, gives an indication of it, which can be traced quite to the external malleolus of the tibia.

"*Tarso-metatarsus.*" The next segment of the lower extremities results, as in most if not all birds, from the fusion of the elements of the tarsus and metatarsus proper.[1] In this species it is an exceedingly compressed bone three and a half inches in length; its sides nearly smooth and quite flat; its anterior and posterior borders grooved for the reception respectively of the extensor and flexor tendons; and separated from the sides by remarkably sharp edges. These edges are so prominent that they impress a very decidedly rectangular shape upon a transverse section of the shaft of the bone. By these grooves, and the fibrous thecæ, which their sharp edges give origin to, the tendons are prevented from encroaching in the least on the sides of the tarsus, which is thus enabled to keep its exceeding thinness; while at the same time they serve to increase greatly the antero-posterior width of this segment of the leg.

The process of bone representing the *os calcis*, rises at the superior end of the bone, on its posterior aspect, as a very conspicuous crest. It is of quite a regular square shape, about a third of an inch long, and of about the same height. The groove denoting its line of fusion with the metatarsus may be traced along its base. Into it are inserted the two tendons of the gastrocnemii; and its substance is perforated by longitudinal canals, through which pass the flexor tendons of the toes. The most posterior of these canals is very large, and transmits the majority of these tendons; anterior to it, that is between it and the metatarsus, are two or three very small canals, lying side by side on the same plane.

The proximal extremity of the bone is marked on each side of the median line by two oval depressions, in which are received the condyles of the tibia. In shape and position the two differ slightly from each other, in consequence of a corresponding difference in the two condyles of the tibia. On either side of the head are the roughened elevations for ligamentous attachments, and for the tendons of the tibialis posticus and peroneal muscles.

The metatarso-phalangeal articulation is extremely interesting. If we examine the foot of

[1] This segment is, by ornithological writers, universally called the "tarsus." Although this name is obviously incorrect, yet in our ordinary zoölogical descriptions of birds, it would seem hardly worth while to reject it in order to apply to it its more strictly proper designation of tarso-metatarsus.

the bird in a fresh state, we find, on closing the anterior toes, that they do not lie all beside each other; but that the inner one lies almost directly behind and between the other two. This arrangement of the toes is in order that the least possible resistance to the water shall be afforded by the toes when they are closed in the forward motion of the feet. To produce this effect, the inner of the three phalangeal heads of the bone is given off before the other two, and not by the side of them; but so far around on the inside of the metatarsus, towards its posterior aspect, that it lies almost directly beneath and behind the middle head. On looking at the bone directly from before, this head is quite hidden from view. In consequence of this arrangement, the line of the articulation of the inner toe is very oblique, to enable the toe to be extended without interfering with the one next to it.

The two other heads which form the distal extremity of the metatarsus, are placed side by side; the middle one being a little the larger and longer. They are very convex vertically, and each is marked with a median groove for the reception of corresponding median ridges on the heads of the phalanges. They are separated from each other by an exceedingly narrow but very deep furrow.

Just above the inner head of the bone, on its interno-posterior edge, is a slight oval depression, on which rests the accessory metatarsal bone. This is a small, thin, flat, falciform, almost unciform lamina of bone, entirely disconnected with the main bone, and simply applied loosely against it. It has no real articulation with the metatarsus; but its distal extremity is thickened for the support of the basal phalanx of the hallux.[1]

[1] I have recently been much interested in examining the very diverse modifications of this *os metatarsale accessorium*, both as regards its shape and its mode of connection with the metatarsus proper. To the end of ascertaining the amount of its variations in these respects, I have examined the halluces of many families and genera; in which labor I have been greatly assisted by my friend, Mr. A. E. Verrill, of Cambridge, Mass., who has taken the trouble to examine many forms which I had not at hand. The result of our observations shows that throughout the *Natatores*, and to a less extent among other *Aquaticæ*, the bone deviates most remarkably from the ordinary type, as presented by the higher orders of *Raptores*, *Insessores*, *&c.* Instead of being very intimately connected with the metatarsus, or even more or less completely anchylosed with it, and consequently immovable, and of a shape and general appearance which unmistakably point to its true character, this metatarsal element becomes totally disconnected with the metatarsus except ligamentously, and is therefore quite loose and freely movable; in some instances there is a smooth articulating surface, which may not impossibly be even lined with synovial membrane, while a frequent elongated and cylindroid shape of the bone itself, joined with its other characteristics, gives it the appearance rather of a third phalangeal segment.

It appears to be among the *Totipalmi* that the bone receives its most peculiar modification in size, shape, and connection. In *Sula*, *Pelecanus*, *Graculus*, &c., this metatarsal bone is nearly as long as the basal segment of the hallux, slightly curved, and of a cylindroid shape. Its proximal extremity has not the perfect articulating surface which its distal end bears; but nevertheless it is smooth, and nearly gives the impression of an articulating facet. Its character as a metatarsal element is greatly over-balanced by its phalangeal features, so that it is only by analogy that we can determine its proper place.

Throughout the *Laridæ*, this bone is found as a small, flattened, rounded, or irregularly polyhedral osseous nodule, very loosely connected with the metatarsus, and again presenting the appearance of a third phalanx, it being half as long as the real basal phalanx. In the anomalous genus *Rissa*, usually described as "tridactyle," both this bone and the proper basal phalangeal segment, are present and quite distinct; the ungual segment being the deficient one.

There is a remarkable peculiarity in the hallux of *Puffinus*, *Thalassidroma*, and probably most of the other genera of the large family *Procellaridæ*. This is, that while the accessory metatarsal is present, the true basal phalanx is wanting. Professor Owen, indeed, says (Todd's Cyclop., p. 288,) that "In the Petrel, however, this accessory metatarsal bone is wanting, although the hallux is present; the two bones of which, are therefore united to the principal metatarsal bone by long ligaments." But, as suggested by Professor Wyman, it seems most rational that in such doubtful cases as the present, we should be guided in forming our opinions chiefly by the shape and position of the bone; and that, too, even if a capsule and synovial membrane exist, as is probably the case in *Graculus*. The bone in the genera now under consideration, has much the characters and general appearances which obtain throughout the allied family *Laridæ;* which would seem to indicate correctly its real nature.

The whole subject of the number of phalanges and their peculiarities in the class *Aves*, is an extremely interesting one, and well worthy of extended investigation. Since the announcement by Cuvier of the normal number of phalanges and of phalangeal segments among birds, the matter does not seem to have received the attention it merits, perhaps on account of the well-known remarkable homogeneity of structure which obtains throughout the class. But I am of opinion that concerning this particular point there probably remain many anomalies, or at least peculiarities, yet to be brought into notice. Writers have not generally in their tables given, by any means, the whole number of the exceptions to the general rule, that are now well known to exist.

Phalanges. The four toes possess the number of segments which normally exist throughout the vast majority of birds; to wit, 2, 3, 4, 5, counting from the hallux to the outer toe. Some special features of each may be noticed.

The hallux is of very moderate length, though comparatively longer than that of many other families of *Natatores*. Its two segments, together with the claw and accessory metatarsal, only measure one and a third inches. Its basal segment is long and very thin, and compressed; its ungual is scarcely more than an osseous nodule for the support of the claw. Although this toe is not without its tendons, it appears to possess little motion, beyond what may be imparted to it by its membranous connections with the next one. It is furnished with a dependent lobe.

The second toe is chiefly remarkable (besides its peculiar articulation with the metatarsus already noticed) for the great length of its basal segment, which considerably exceeds that of the other two segments combined.

All the phalanges of the middle toe are very stout and strong, much surpassing those of either the inner or outer toes in this respect. It is intermediate in length between the inner and outer toes.

The outer toe is the longest of all. Its fourth segment, the penultimate one, presents the peculiarity of being considerably longer than either the second or third.

The mechanism by which the toes are separated from each other, or abducted, at the same time that they are extended, forms an interesting feature in the feet of this and other birds. The metatarso-phalangeal articulation is a strict ginglymus, not admitting of lateral motion, nor of rotation. But the median grooves of the heads of the metatarsal bone, instead of running directly perpendicularly over the joint, are placed a little obliquely; *i. e.*, that on the under head runs upwards and inwards; that on the middle head slightly outwards; that on the outer head is much more oblique. The planes of the heads of the metatarsus are also peculiarly twisted; so that on their inferior aspects they all look towards each other; but as they mount upwards, gradually turn outwards or away from each other. Now the heads of the phalanges, when raised by the extensor tendons over the joint, follow the direction of these oblique planes, being guided by their median ridge which fits in the median sulcus in the metatarsal bone; and so, by the time they are fully extended they also all look away from each other; and the webs are by this means spread.

Thus the toes when extended must also be carried from each other; and they cannot be approximated except when flexed. The intention of this peculiarity is evident. The more forcibly the toes are pressed against the water the wider their webs are spread by the resulting separation of the toes; whereas if the toes could be approximated when in a state of extension, it would require constant effort to preserve the expansion of the webs.

Myology.

Cutaneous muscles. The principal of these is the large muscle which lies immediately beneath the skin of the neck and breast, so closely adherent to the skin as to be taken off with the latter in ordinary skinning. It has quite an extensive origin on the breast, extending two or three inches on each side of the median line. The greater number of its fibres converge to pass up on each side of the median line of the neck, as narrow slips; but a thin, yet compact layer of longitudinal fibres completely encircles the neck, reaching quite to the occiput.

A pair of musculo-tendinous slips arise by three separate digitations from near the extremities of the fifth, sixth, and seventh vertebral ribs; these digitations converge, and pass upwards and backwards to be inserted into the skin just over the apex of the scapula. These muscles are apparently offsets from the serrati magni.

Another pair of musculo-tendinous slips pass to the skin, from the muscles just external to, and an inch below, the acetabula.

Muscles of the Trunk.

These need detain us but for a moment; their arrangement is as usual exceedingly complex, and probably presents no special peculiarities. It is only necessary, therefore, to notice the general features of the muscles of this region.

The head of the bird is large and heavy, and its neck comparatively long. From the tip of the bill to the first rib, measures more than from the latter point to the end of the coccyx. In flying, as well as in diving and swimming under water, this ponderous head and neck are held straightly outstretched. To enable the bird to do this, and to execute the varied and extensive, as well as exceedingly rapid movements of the head and neck necessary to secure its living prey, the muscles acting upon these parts are well developed. Their general disposition is as follows: —

On the back the opisthotenar muscles commence about opposite the crests of the ilia, and extend along the fossæ on each side of the spinous processes of the vertebræ. But as there is very slight mobility of this portion of the spine, the muscles are comparatively small and flat, and are moreover tendinous for a considerable portion of their extent.

On the back of the neck, just anterior to the shoulders, where the greatest strain from the weight of the head and neck is experienced, the aggregate bulk of the muscles is exceedingly extensive, much greater than at any other point along the spine. They are also almost wholly carneous, each of the numerous slips being muscular rather than tendinous, almost from their very origin. This is the point where the greatest mobility is required, as well as the greatest strength; and the two indications are fulfilled by the preponderance of the contractile over the non-contractile portions of the muscles, together with the increase in actual bulk of the muscular tissues.

Passing along the neck toward the head the bulk of the muscles decreases, and they become more tendinous, to the middle, but from this point toward the head their size and fleshiness again increase, until near the occiput the aggregate volume of the complexus, trachelo-mastoideus, &c., amounts to nearly as large a mass as is found at the root of the neck. This is necessary for the adequate support of the large and heavy head.

Biventer cervicis. The pair of muscles thus homologized by comparative anatomists, and which exists so constantly throughout the class, is very distinct in this species. Throughout their whole extent they receive no slips, and have no accessory attachments. They arise from the spines of the lowest cervical, or anterior dorsal vertebræ, as two slender round fleshy bellies; their central tendons are two or three inches long, after which the muscles again become fleshy, and as such are inserted side by side into the superior extremity of the occipital spine. The muscular portion thus considerably exceeds the tendinous.

The other individual muscles of the neck do not require special mention in this connection.

The muscles moving the caudal extremity of the spine, do not present any special peculiarities, with the exception of the *cruro-coccygeus*, or "*femoro-coccygeus*." This, from its origin and relations, may be more conveniently considered in connection with the muscles of the posterior extremities.

Of the abdominal muscles, the *obliquus externus vel descendens* is particularly remarkable for its extensive origin, which causes it to form an investment, not only of the abdominal, but also of the greater part of the lateral thoracic parietes. It arises by broad aponeurotic digitations from the retrocedent processes of about seven ribs; from the margins of the ilium; from the horizontal ramus of the pubis; and from the posterior margin of the sternum, overlying a great part of the broad xiphoid cartilage; its fibres (as usual in the class) are directed inwards, with but a moderate inclination downwards; and continue carneous almost to the median raphé, there being but a short aponeurosis before the insertion into the "linea alba."

Muscles of the Upper Extremities.

Pectorales. A remarkable peculiarity of the great pectorals is that they are united with each other by an extensive band of transverse fibres which pass across from one to the other just anterior to the keel of the sternum, lying upon the clavicular symphysis, and covering these bones for an inch or more.

The fleshy mass commonly called the "*pectoralis major*," consists of three portions, so very distinct from each other, in their origins and insertions, as well as in the motion they impress upon the humerus, that I prefer to consider them as distinct muscles. They are more distinct than the three *glutœi* of the human subject.

The first pectoral, or "*pectoralis maximus*," is large, long, and broad, but very flat, and not thick. It arises from the whole of the clavicle; from the lower half of the fibrous septum which stretches vertically above it; from the side of the keel of the sternum (except that part occupied by the succeeding); and from the edge of the sternum all around, as high as the articulation of the last sternal rib. The mass laterally overlaps the edges of the bone; posteriorly is continuous with the fibres of the abdominal muscles. In the middle of the muscle is a broad longitudinal tendinous septum, which divides the mass into a greater portion, with origins as above, and a smaller part, which arises from an oblique ridge upon the face of the sternum. The fibres converge without twisting to the ordinary insertion.

Pectoralis medius. Arises from the inner half of the anterior third of the keel of the sternum (all that portion not occupied by the preceding); from the sternum itself as far as an oblique ridge which runs from the sterno-coracoid articulation to the keel, and separates this muscle from the next; and from the upper half of the supra-clavicular fascia. Its fibres converge to pass under a large trochlear surface of the coracoideum (converted into a foramen by the apposed clavicle) to their insertion by a stout rounded tendon into the ridge of the humerus near its extremity.

It is a powerful external rotator of the humerus; and its further action elevates the humerus directly from the back, carrying its distal extremity in the arc of a vertical circle toward the head.

Pectoralis minimus. Situated posterior and just external to the preceding, this muscle arises from the outer half of the broad base of the coracoideum, and the contiguous portions of the sternum. It is much smaller than the preceding, with the posterior border of

which its anterior border is parallel and in apposition. It runs forwards and outwards, and is inserted directly into the internal tuberosity of the humerus.

It adducts the humerus toward the body, and also depresses it when elevated.

Latissimus dorsi. The two portions into which this muscle is divided are perfectly distinct as to their origin, direction, and insertion. The anterior portion is a narrow, thin, delicate, ribbon-like muscle, arising from the spines of about three vertebræ opposite the middle of the scapula; passing directly outwards, over the scapular muscles, superficial to them all, it is inserted into the back part of the humerus, two inches below its head, opposite the insertion of the deltoid, close by the insertion of the posterior slip of the same muscle.

The posterior division of this muscle, larger than the preceding, and broad and fan-shaped at its origin, arises from the last four or five dorsal vertebræ; its fibres rapidly converge, and it is inserted into the humerus close by the side of the preceding portion.

These muscles draw the humerus directly backwards, slightly rotating it outwards.

The scapula is connected with the spine by the two layers of muscular fibres, — the *trapezium* and *rhomboideus*, — as usual in the class. The fibres of the two planes decussate at right angles, in the ordinary method.

The *serratus magnus* is very small and inconspicuous, arising by three digitations only, passing upwards and forwards, to its usual insertion into the apex of the scapula.

Muscles of considerable size, the homologues of the *teretes*, *infraspinatus* and *subscapularis*, proceed from the whole length of the scapula, below the origin of the extensor of the forearm to their insertion into the outer and posterior aspect of the head of the humerus. They rotate inward, and retroduct the humerus.

The *supraspinatus*, smaller than the preceding, and quite distinct from them, arises from that portion of the scapula above the origin of the extensor cubiti; and passes as a rather broad and thin muscle, to be inserted into the back of the shaft of the humerus, one and a half inches below its head, by a thin tendon, fully an inch in breadth. It rotates the humerus slightly outwards, and directly retroducts it.

Deltoid. Arises just at the coraco-clavicular articulation. It is small and weak, only about one and a half inches long; it passes directly over the shoulder joint, to be inserted into the distal extremity of the external humeral crest.

Immediately over the deltoid, and lying superimposed upon it, is the origin of the *extensor plicæ alaris.* As this muscle passes over the most elevated portion of the humeral crest, it gives off a tendinous slip which is inserted into the crest, after which it passes on to its insertion into the anti-brachium and metacarpus.

Biceps flexor cubiti. This is rather a "biped" than a "biceps" muscle; having apparently but one origin, and two insertions. It arises from the tip of the coracoid; passes as a rounded tendon along the depression between the anterior tuberosity and external oblique ridge of the humerus; continues single to the end of the first third of the humerus, where it divides into two fleshy bellies. The larger of these is inserted by a long round tendon into the tuber radii; the other seems lost in the fascia of the forearm; being also intimately blended with the fascia over which stretches the cutaneous fold at the bend of the elbow.

A small muscle arises from the anterior aspect of the humerus, about half an inch above its condyles; passing down mesiad of the tendon of the biceps, between it and the pronator radii teres, it is inserted into the inner border of the ulna, an inch or more from its head. This muscle lies more upon the forearm than upon the arm; its whole action, however, is that of a flexor of the forearm; thus being perhaps analogous to the *brachialis anticus.*

The *triceps extensor* of the forearm is divided into two perfectly distinct muscles, which may be called the "long" and "short." The former arises fleshy from the scapula half an inch below the glenoid fossa, passes as a stout, fusiform, fleshy belly to within an inch and a half of the olecranon, where it becomes tendinous; runs through a groove in the outer condyle of the humerus, to be inserted into the olecranon on its radial aspect. About an inch from its origin it gives off a small but distinct flat tendinous slip, which passes obliquely upwards and backwards to be inserted into the humerus; it being joined by a similar slip given off by the latissimus dorsi, which is inserted with it.

The other portion of the extensor is perfectly distinct, having a different origin and separate tendon of insertion. It arises from the posterior aspect of the shaft of the humerus for nearly its whole length; becomes tendinous near the elbow, and passing through a separate groove in the inner condyle, is inserted into the corresponding side of the olecranon, just opposite the insertion of the longer extensor.

Pronator radii teres; Supinator brevis. Arising respectively from the internal and external condyle, these two muscles converge towards their insertions into the radius exactly opposite each other. They directly antagonize each other; but, from the almost complete absence of pronation and supination in a bird's antibrachium, probably act together, and thus serve to steady the radius.

Extensor metacarpi radialis longior. As usual, a large muscle, the first one given off on the radial aspect of the limb. Arises high up on the external condyle by a flattened tendon, which soon changes to a fusiform fleshy belly; again changes, about the middle of the forearm, to a rounded tendon; this passes along a deep groove in the head of the radius, to be inserted into the radial aspect of the metacarpus. In its passage along the radial groove it is accompanied by the tendon of the next muscle.

"*Extensor metacarpi radialis brevior.*" *(Extensor proprius pollicis?)* This very slender small muscle arises from, and lies along, the ulnar aspect of the radius, its delicate tendon passing forwards along the radial groove with that of the preceding, to be inserted into the base of the pollex. Its tendon is more or less blended with that of the preceding; and any motion which it can impress upon the pollex must at best be but slight. It appears to have rather the effect of an auxiliary extensor of the metacarpus, aiding the action of the preceding.

A small, very slender, but long muscle arises from the internal condyle; lies along the ulnar aspect of the radius, beneath the preceding; its delicate rounded tendon passes through a notch in the head of the ulna, and runs obliquely along the side of the metacarpus; divides into two slips, one of which goes to the base of the pollex, the other to the base of the first digit. This muscle adducts the thumb, and bends the metacarpus upon the anti-brachium.

Flexor metacarpi radialis. Arises from nearly the whole length of the radial aspect of the ulna, and from the inferior aspect of that bone for its distal fourth. Its tendon passes obliquely over to the head of the radius; and is received into a deep groove, which carries it transversely across to the outer aspect of the wrist joint, where it dips deeply down to its insertion into the head of the metacarpus. This muscle seems to act as a flexor in the following interesting manner: When the hand is extended, or rather abducted, the head of the metacarpal bone, revolving in the radio-carpal articulation, carries with it the tendon, by which means the muscle is put upon the stretch. The contraction of the muscle, therefore, will of course tend to restore the bone to its original position, and thus fold or adduct the pinion.

Flexor carpi ulnaris. Of moderate size, fusiform shape, fleshy for nearly its whole extent; lying along the inner aspect of the ulna, its tendon inserted into the ulno-carpal bone, just in the angle of the wrist joint. It is a direct flexor or adductor of the metacarpus.

The phalangeal flexors and extensors do not seem to require special notice.

Muscles of the Lower Extremities.

As might be expected from the peculiar formation of the bony framework of the lower extremities, and especially the shape of the pelvis, the muscles of this part of the bird present many interesting features, as regards size, shape, position, line of traction, etc. From the great length, and extreme narrowness and flatness of the pelvis, the muscles proceeding from it to the femur and tibia, or fibula, are of peculiar shape, and have frequently unusual actions upon the bones they move. Thus, the line of traction of the pubo-femoral muscles is such, that their action as femoral adductors is almost entirely lost, and they have become rather extensors of the thigh. Other muscles again, ordinarily flexors or extensors, seem to exert their chief action in producing the rotatory movements of the leg and foot upon the thigh which in this genus are so perfect and extensive. From the extreme tenuity of the sacrum, several muscles seem to take their origin from the spine itself rather than from the pelvis. From these peculiarities of position and action, I have found considerable difficulty in homologizing several of the muscles. I have generally noticed them in the order in which they successively appear in the prosecution of the dissection.

Sartorius. The first muscle given off to the lower extremities, arises apparently from the spine of the dorsal vertebra about opposite the apex of the scapula; passes downwards and outwards at an angle of 45°, overlying the *latissimus dorsi*, of a uniform width of about three fourths of an inch, to be inserted, by a flattened tendon, into the inner aspect of the projecting spine of the tibia, half an inch *above* the joint. It is fleshy throughout, except just at its origin and insertion.

It is a powerful internal rotator of the leg; and to a less degree, an extensor.

A broad, thin, fan-shaped muscle, the "rectus femoris," as homologized by most comparative anatomists, arises from the median line of the sacrum for a distance of four inches, commencing just below the origin of the preceding, with the lower border of which its upper border is parallel and in contact; lies superimposed upon the vasti, glutæi, and cruræus; its fibres pass directly outwards, converging from this extensive origin to a narrow flat tendon, which passes over the external condyle of the femur, to be inserted into the head of the fibula. The muscle is tendinous for an inch or more at its insertion, and just at its origin; otherwise fleshy.

It is a perfect external rotator of the tibia, and therefore the antagonist of the preceding. From its insertion and the direction of its fibres it can have little or no effect as an extensor. Its shape is such that with its fellow of the opposite side it forms a perfect *trapezium* across the back of the pelvis.

Biceps flexor cruris. A thin fan-shaped muscle, not unlike the preceding in shape, arises from the pelvis near the median line, from opposite the acetabulum as far down as the tuber ischii, being therefore partially overlapped by the preceding muscle. From this extensive origin of about three inches, the fibres proceed directly outwards, converging to a flattened, then to a rounded, tendon. This tendon passes through a perfect fibrous loop,

given off from the femur, (to be more particularly described hereafter,) by which its direction is changed; now passing with a considerable degree of obliquity downwards, it is inserted into a tubercle on the outer aspect of the fibula, one and a half inches below the knee-joint.

A direct and powerful flexor of the leg. In the passage of its tendon through the fibrous loop, and the consequent change in the direction of the line of traction, is seen a beautiful mechanism by which the force of the stroke as well as the extent of motion is increased when the backward movement of the leg is nearly completed; *i. e.*, at the moment when the most vigorous impulse is requisite. This muscle is doubtless the biceps flexor, from its insertion and mode of action, though there is nothing at all bicipital in its shape.

Glutæi. Filling the concave dorsum of the ilium, and lying close along the spine, is a mass of muscular tissue, which on its vertebral aspect is intimately blended with the spinal muscles proper, and with which some of its fibres appear superiorly continuous. I found it impossible to determine exactly the limits of the attachments of this muscle. It is incompletely divisible into two portions, which are however intimately united anteriorly. The largest of these — that nearest the spinal column — passes backwards to be inserted into the great trochanter; the other lies nearly parallel, but its tendon is inserted further down on the outer and anterior aspect of the femur.

The first of these muscles evidently rotates the femur inwards. The other is directly in the line of flexion; and though it cannot have much power, from its high insertion into the femur, it probably aids to flex, and somewhat inverts that bone. These muscles seem from their position and insertion, to be the *glutæus medius* and *minimus*, though from the peculiar shape of the parts, their actions are not identical with those of the human species.

The muscle which probably represents the *glutæus maximus* is quite distinct from the others and smaller than either of them; and from the elongated shape of the pelvis, is entirely *caudad* of the femur, instead of lying in the same region and obliquely in the same plane with the other glutæi. It is a small flattish muscle, one and a half inches wide, lying close along the sacrum, on the pelvis, from an inch above the tuber ischii, to the femur. Its tendon runs forwards and obliquely outwards from the spine, to be inserted into a tubercle on the externo-posterior aspect of the femur, just below the trochanter, and just opposite the insertion of the above described *glutæus minimus*. The whole origin and inferior surface of the muscle is fleshy; but its tendon of insertion continues along its external surface to within an inch of its origin.

As in the human species, this muscle extends and everts the thigh. It directly antagonizes the *glutæus minimus*.

Obturator. The obturator foramen is filled by a muscle which arises from its whole circumference, lying between two layers of fasciæ. The small rounded tendon of this muscle runs forwards to be inserted into the posterior aspect of the great trochanter. It directly rotates the thigh outwards.

Crurœus. A large muscular mass, lying upon the anterior aspect of the femur. Instead of converging to a tendon for its connection with the tibia, it has a very extensive muscular attachment to the posterior face of the whole length of the tibial spine that projects above the knee-joint.

This is the direct extensor of the leg. Although so short, only as long as the short

femur, yet its action must be powerful, from the amount of contractile fibre it contains and from the great increase of leverage obtained from the projecting spine of the tibia.

Vasti? On either side of the preceding lies a smaller muscle, having its origin from the femur near its head. They proceed over the femoral condyles to be inserted respectively into the inner side of the head of the tibia, and into the head of the fibula close to the articulating surface.

From the origin and position of these muscles, they seem to represent the *vasti;* but by a slight variation in their insertion, their function is entirely changed. They can exert but very slight, if any, action as extensors of the leg. They are *rotators* of the leg upon the thigh. The internal one acts conjointly with the sartorius; while the external one is intimately blended with the tendon of the broad fan-shaped muscle, above described, and referred to the rectus femoris.

It will thus be seen, that of the four muscles which in the human species conjoin to form a "quadriceps extensor cruris," only one, the cruræus, is here left as a proper extensor. The rectus joins the vastus externus, and both are together inserted into the head of the fibula, to act rather as external rotators; while the vastus internus forms an internal rotator, in which action it is assisted by the sartorius.

The "pubo-femoral" muscles, — the proper adductors of the thigh, — are represented by a broad plane of muscular fibre, which arises from the whole length of the horizontal ramus of the pubes, and from a considerable portion of the obturator fascia. From this extensive origin the muscle converges as a thin flat plane, to be inserted by a broad tendon into the lower half of the femur. I was not able to divide these fibres into distinct muscles.

A large, somewhat flattened muscle arises from near the tuber ischii, and from the sides of the sacrum nearly as far as the femur; also from the surface of the pelvis not occupied by the glutæus maximus, which it overlies, and proceeds obliquely upwards and outwards, to be inserted into a tubercle on the inner and posterior aspect of the femur, a little below its middle. On the external surface, the tendinous portion of the muscle extends to within two inches of its origin; but on the internal aspect the muscle is fleshy, nearly to its point of insertion.

The first of the two preceding muscles is of course homologous with our adductors, and the latter would seem from its insertion to belong to the same class. But however this may be, the shape of the pelvis, and the relative position of the femur are such, that any action they may have as adductors can be but slight, and must be greatly overbalanced by their more energetic action as *extensores femoris.*

In connection with the muscle last described, there is to be noticed one belonging to quite a different set, viz. the *"femoro-coccygeal."* This is a small, narrow, ribbon-like muscle arising from the base of the coccygeal vomer. It proceeds forwards, fleshy, for two and a half inches, changes suddenly to a small rounded tendon, which lies along the outside of the tendon of the muscle last described. They soon become intimately blended together, and proceed as one tendon to their insertion into the femur.

There is thus a strong "guy" proceeding on each side of the pelvis from the femur to the coccyx, reminding one irresistibly of the tiller-ropes of a boat's rudder. Acting together they serve to steady the tail; more strongly contracting, they draw it downwards; while either acting alone draws the tail obliquely downwards and to the corresponding side.

Semi-tendinosus. Arises from the tuber ischii, being at its origin intimately blended with

the second of the two femoral "adductors" just described. It crosses obliquely over the coccygeal muscle; passes outwards and forwards, and is inserted by a narrow flat tendon into the tibia, about an inch below the joint.

Semi-membranosus. Arises from the pelvis about midway between the acetabulum and tuber ischii, and is inserted by a broad membranous tendon into the crest of the tibia just above the insertion of the preceding. It is a thin flat muscle, with a tendon fully as wide as the fleshy portion.

These two muscles are the proper flexors of the leg upon the thigh. Their tendons form the "inner hamstrings," and from their situations, relations, and uses are undoubtedly to be homologized with the *semi-tendinosus* and *semi-membranosus.*

In my dissections I failed to detect a "gracilis" muscle; or any connection of a tendon of a crural extensor with a digital flexor, by which flexion of the toes is produced by the mere bending the knee and ankle-joints, as is the case with the *Insessores*, etc. I do not think that such a mechanism exists, at least to any marked degree, although I may be mistaken.

Considering collectively the muscles which act upon the thigh and leg, it will be noticed that by far the greater part of their combined force is exerted to produce powerful *extension* of the thigh and *flexion* of the leg, with a free *rotation* of the latter upon the former; while the power of flexion of the thigh, and extension of the leg, is reduced in a proportionate degree. The importance of such a disposition of the muscular forces of the parts to the full development of vigorous natatorial power, is too evident to need comment; for the bringing forward of the leg requires but very slight effort in comparison with that necessary to produce the energetic backward stroke by which the bird is propelled forward. Now, in examining the muscles of the leg and foot, we shall find that they are so disposed as to most effectively continue the powerful backward stroke which began at the hip-joint. The extensors of the metatarsus vastly predominate both in number and size over the flexors. No less than seven tendons pass over the posterior aspect of the tibio-tarsal articulation, while only three are found upon its anterior face. I will notice the more important of these muscles.

Tibialis anticus. Arising from the very tip of the projecting spine of the tibia, and from the whole anterior aspect of that spine down to the joint, it lies along the face of the bone for its whole extent, though no more fibres take origin from it. It is fusiform in shape. Its tendon passes directly over the anterior surface of the joint, being bound down by a transverse ligament, and is inserted into the head of the metatarsal bone. It directly flexes the tarsus.

Extensor digitorum communis. Much smaller than the last, lying beneath and internally to it. It is somewhat penniform in shape, its tendon running up for some distance on its inner edge, its outer surface being covered with dense fasciæ. It arises from the anterior aspect of the spine of the tibia, down as far as the knee-joint, for which extent it is intimately blended with the muscles by which it is surrounded. After passing the joint, it becomes distinct from any other muscle; but fibres continue to take origin from the face of the tibia for nearly its whole length. Its tendon passes behind and internal to that of the tibialis anticus, passes through an osseous canal formed by the bony bridge which stretches across between the malleoli, and runs along the anterior edge of the metatarsal bone, in a deep sulcus; about half an inch from the end of the bone, it gives off the tendon which goes to the inner anterior toe; this at once divaricates in a special groove, while the tendon

proceeds to the head of the metatarsal bone, just over which it splits into two for the middle and outer toes. The tendons extend to the bases of the last phalanges on each toe.

Peroneus. Much smaller than either of the others, this muscle arises from the fibula for the greater part of its length. Its tendon passes through a separate canal in the annular ligament, on the outer aspect of the joint, and proceeds obliquely backwards, to be inserted into the posterior border of the metatarsal bone, just at its base. From the peculiar position of the tendon where it is bound down, as well as by its insertion, it can have little or no effect in moving the tarsus backwards or forwards. When the tarsus is extended it may weakly aid in extending it; but its principal office is evidently to direct and restrict the rotatory movements of the tibio-tarsal joint. It quite powerfully rotates it outwards, and antagonizes the *tibialis posticus* on the outer side of the joint.

Gastrocnemii. In the *gastrocnemii* there is seen the same plan as was noticed in the "*triceps*" *extensor cubiti*, viz. — a tendency to divide into two distinct muscles. It is not, however, so strongly pronounced as in the former instance, though the three origins of the gastrocnemius are even more widely diverse.

The inner, or rather the anterior *gastrocnemius* lies upon the inner and anterior aspect of the tibia for its upper two thirds, afterwards crossing the leg obliquely, to get upon its posterior aspect. It has two heads; one arising fleshy from the apex of the tibial spine, from the whole anterior face of the upper two thirds of the bone, and from the fibrous septa between it and other muscles; the other from the inner condyle of the femur; the tendons of the *semi-tendinosus* and *semi-membranosus* being interposed between them.

The posterior or outer *gastrocnemius* arises from the "*linea aspera*" for nearly two thirds its length, and from the outer condyle; also receiving attachments from the muscle described as the *rectus femoris.*

These two portions of the muscle, thus diversely arising are fleshy to within two inches of the heel. There they change into two stout round tendons, entirely separate from each other. A little above their final insertion they fuse into one broad, thick, very powerful tendon, which passes directly over the posterior aspect of the joint, (overriding the tendons of the other muscles,) and is inserted into the base of the bony protuberance on the back of the metatarsus.

At the mesial edge of the insertion of the last described portion of the gastrocnemii, there proceeds down from the femur a most perfect sample of an aponeurotic loop. This loop encircles the tendon of the *biceps flexor cruris*, and changes the direction of its line of traction as much as does the loop which in our species binds down the tendon of the *digastricus* to the hyoid bone. It runs down from the femur as a distinct narrow fibrous band; embraces the tendon, and returns upon itself, the two ends of the loop being inserted side by side. This loop is more or less blended with the fibrous investment of the under surface of the gastrocnemius.

The dissection and examination of the remaining muscles of the back of the leg is exceedingly difficult. They are all more or less intimately united with each other, throughout the greater part of their muscular as well as tendinous structure. They arise from the outer and posterior aspects of the bone, and from the intermuscular septa between one another. They become tendinous at very various points. Their tendons, however, are all aggregated together to pass directly over the posterior aspect of the heel. Just over the joint, nearly all are enclosed in one large dense shiny white mass of fibro-cartilage, through which each tendon bores a canal for itself. Leaving this sheath, all but one (the *tibialis posticus?*)

pass through the canals of the bony protuberance which is superimposed upon the base of the metatarsal bone, and proceed to their different digital insertions. This bony canal is subdivided by osseo-cartilaginous septa into three divisions: a quite large central posterior one, through which the majority of the tendons pass; and two or three smaller latero-anterior ones, for special tendons. I will notice two of these muscles which are quite distinct as to their insertions, and consider the others collectively as the digital flexors.

Tibialis posticus? A muscle which I thus doubtfully homologize, not from its position, but from its insertion and evident action, arises from the very apex of the tibial spine, and from the fibrous septa between it and contiguous muscles. Its tendon passes with the others through the fibro-cartilaginous envelope; but then divaricates, to be inserted into the inner aspect of the base of the metatarsal bone. It is the evident antagonist of the peroneus already described; directing and limiting the rotation of the tarsus.

The inner anterior toe has a special flexor of considerable size. Its tendon passes over the back of the joint, through one of the smaller divisions of the bony canal; and proceeds to its insertion along a deep groove on the posterior edge of the metatarsal bone.

The *common flexors of the digits* as usual consist essentially of two sets, a *perforans* and *perforatus*, though the expressions "superficial" and "profound" do not here hold good, as they have no such relative position. The tendons of the two sets, however, do really lie superimposed upon each other, and the one divides for the passage of the other, much as in the human species. The interlacing of the tendons of the different flexors is exceedingly intricate. Almost every one sends tendinous slips to one or more of the others; so that the most simultaneous action of all the toes is secured; and though the fleshy bellies of some of the tendons have diverse origins, the combined effect of the whole seems to be that of a single powerful flexor.

Explanation of Plate V.

Fig. 1. — Superior aspect of skull.

Fig. 2. — Lateral aspect of skull.

Fig. 3. — Inferior aspect of skull.

Figs. 1, 3, are without the inferior maxillary. These three figures are of the natural size.

Fig. 4. — Pelvis and posterior extremities *in situ*. One half the natural size.

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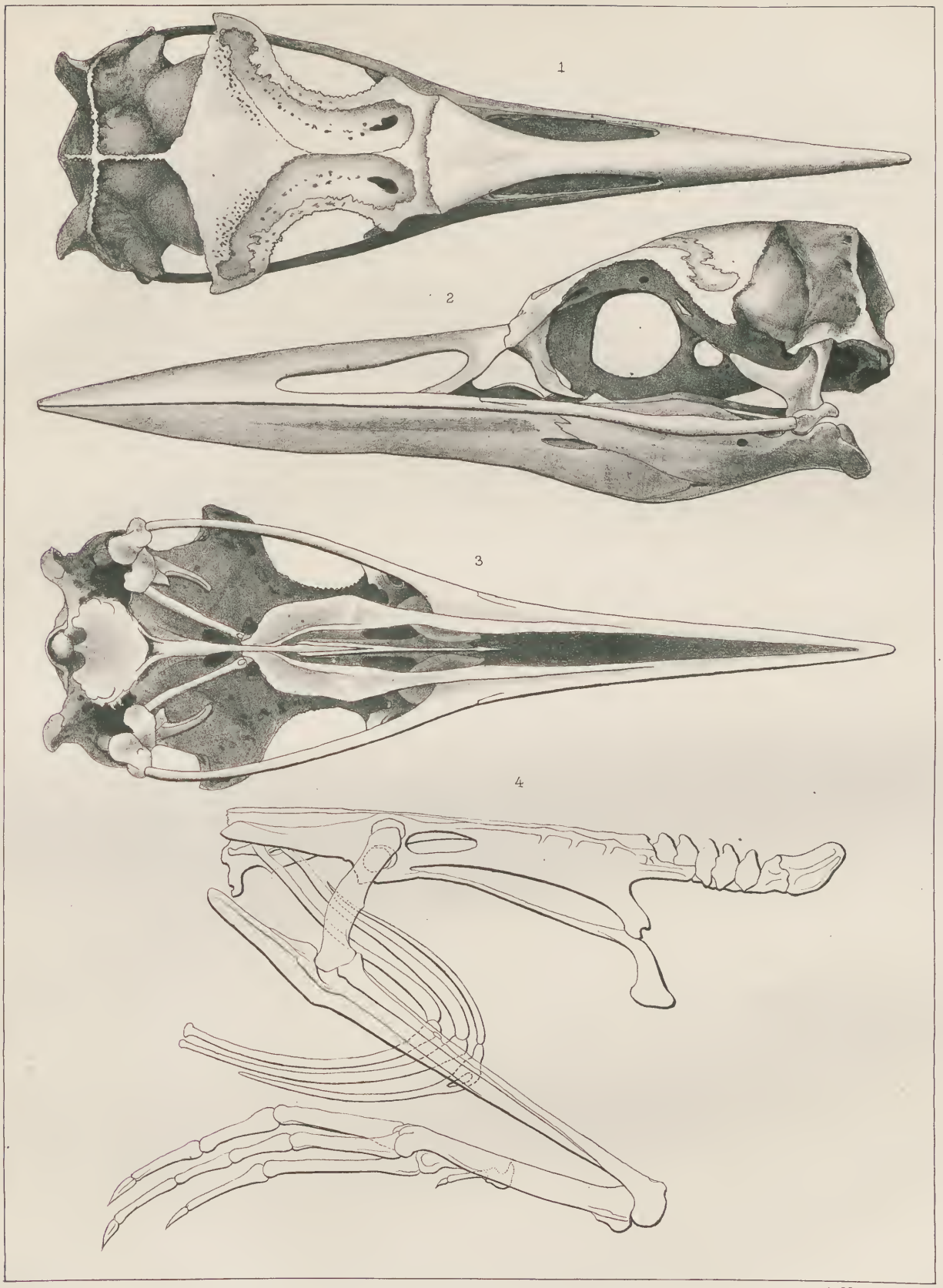

A. Meisel Lith.

Coues on the Osteology of Colymbus torquatus.